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DESCRIPTION OF A NEW SPECIES OF COCCOPHAGUS RECENTLY INTRODUCED INTO CALIFORNIA*

BY

HAROLD COMPERE

Coccophagus gurneyi n. sp. is one of five species of beneficial insects recently introduced from New South Wales into California to aid in controlling the citrophilus mealybug, *Pseudococcus gahani* Green. This parasite is rapidly becoming abundant in certain orchards of Orange and Los Angeles counties where it was first colonized.

Coccophagus gurneyi n. sp.

Figures 1–2

Coccophagus sp. Compere, California Citrograph, vol. 13, no. 9, pp. 318, 346–349, July 1928.

A medium sized species, predominantly black with yellow legs and a conspicuous band of yellow across the basal part of the abdomen. Structurally not greatly unlike *Coccophagus lecanii* (Fitch). In coloration suggestive of *Coccophagus cinguliventris* Girault from which it is readily distinguished by structural differences.

FEMALE—

General color shining black. Basal one-third, or so, of the abdomen orange to yellow. Frontovertex brownish to blackish with a pattern of orange, brown, or yellow lines. Face, cheeks, and mouth parts usually yellow. Sometimes face and cheeks brownish. Tips of mandibles brown. Antennal scape yellow, flagellum yellow with dark sensoria. Parapsides sometimes more or less suffused with brownish yellow. Tegulae and sclerites in proximity to insertion of fore wings more or less suffused with brownish yellow or orange. Legs mostly pale lemon yellow, the tibiae and tarsi faintly brownish, apical tarsal joints dusky.

Pedicel about one and one-half times as long as wide and about one-half as long as the first funicle joint. First funicle joint plainly the longest, more than twice as long as wide. All funicle joints successively decrease in length and increase in width so that the third

* Paper No. 198, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

joint is about one and one-half times as long as wide. Club about as long as the preceding two funicle joints combined and slightly but plainly wider than the distal funicle joint. Antenna and details of sensoria as in fig. 2*c*.

Mandibles as in fig. 2*d*.

Fore wings hyaline or nearly so. Cilia of disk moderately dense. A well defined hairless streak beneath the marginal vein separated by four or five irregular rows of cilia from an upbending hairless streak extending from the base of wing along the posterior margin. Marginal fringe short. Marginal vein slightly but appreciably

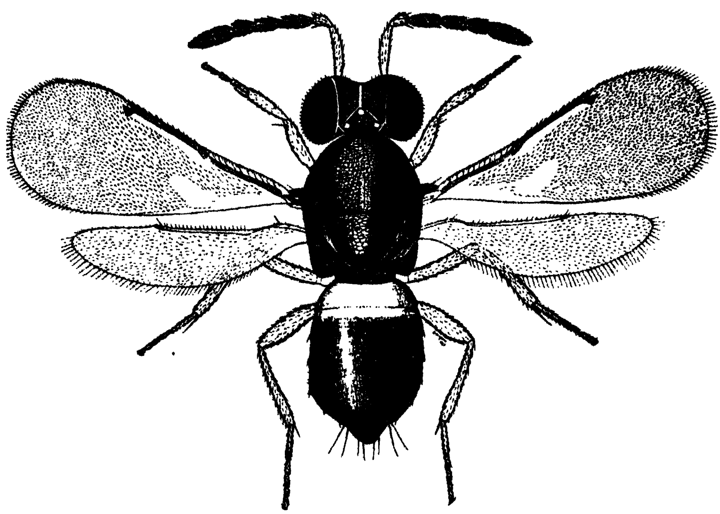

Fig. 1. *Coccophagus gurneyi* n. sp. Female.

shorter than the submarginal vein. Postmarginal vein indistinct but apparently produced forward about as far as the stigmal vein. Detail of venation as shown in fig. 2*b*.

Scutellum slightly wider than long (6:5) and not quite so long as the mesoscutum (10:13). Abdomen about as long and as wide as the thorax. General proportions of the head, thorax, and abdomen as shown in figure 1.

Frontovertex with numerous short, moderately coarse, black setae, those on the face and cheeks finer and pale. Eyes plainly pubescent. Mesoscutum furnished with more or less scattered, short, black setae, those along the parapsidal and scutellar sutures plainly stronger. The posterior median pair of setae on the mesoscutum about as large as the setae on the axillae. Each parapsis with four black setae. Each axilla with two strong black setae. Scutellum with three pairs of large black setae, the anterior pair closest together, the posterior pair only a trifle larger than the median and anterior pairs. Setae on the sides of the basal abdominal segment very fine and pale. Second, third, and fourth tergites each with a broadly interrupted row

of black setae somewhat finer than those on the mesoscutum. Fifth and sixth tergites each with a complete row of setae. Seventh tergite with scattered setae. Apex of fore and middle femora with a pale seta at apex beneath. Middle tibial spur about two-thirds as long as the basitarsus.

Measurements in mm. as follows: Length of average size specimen 1.04. Scape .16 long by .0328 wide. Pedicel .0496 long by .0384 wide. First funicle joint .09 long by .0384 wide. Second funicle joint .0776 long by .0392 wide. Third funicle joint .0688 long by .0432 wide. First club joint .0616 long by .0480 wide. Second club joint .0472 long by .0464 wide. Third club joint .0456 long by .0312 wide. Marginal vein .26 long. Submarginal vein .28 long.

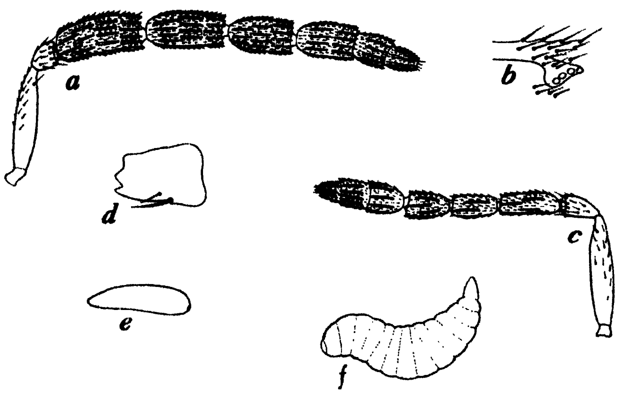

Fig. 2. *Coccophagus gurneyi* n. sp. *a*, male antenna; *b*, stigma female; *c*, female antenna; *d*, mandible; *e*, newly laid egg; *f*, partly grown larva.

MALE—

Abdomen shining black. Thorax black except for the parapsides which are orange or brownish yellow and blotched with blackish on the expanded part. Face, cheeks, and scape lemon yellow. Flagellum brownish. Middle and hind coxae mostly, if not completely, black. Hind tibiae dusky, fore and middle tibiae and all tarsi slightly brownish. Remainder of legs lemon yellow.

Antenna as in fig. 2*a*.

Described from 50 females and 10 males (*holotype* female, allotype, and paratypes) propagated on *Pseudococcus gahani* Green in the insectary of the Citrus Experiment Station at Riverside, California, July 24, 1928. Types to be deposited in the United States National Museum. The parent stock was obtained by the author at Sydney, New South Wales, where specimens were reared from *Pseudococcus gahani* Green, *Pseudococcus longispinus* (Targ.), and from two undetermined mealybugs. This is the first species of *Coccophagus* recorded as parasitic on mealybug. A detailed report on the biology and life-history of this parasite is in preparation. Figures 2*e*, *f*, represent a newly laid egg and a partly grown larva.

THREE NEW SPECIES OF THE HYMENOPTEROUS FAMILY ENCYRTIDAE FROM NEW SOUTH WALES*

BY

P. H. TIMBERLAKE

The three species here considered were discovered by Mr. Harold Compere at Sydney, New South Wales, during his search for parasites of the citrophilus mealybug, *Pseudococcus gahani* Green. *Tetracnemus pretiosus* and *Anusoidea comperei* were definitely reared from this mealybug, and the former species is now being propagated and colonized in large numbers in California. The third species, *Anarhopus sydneyensis,* was not reared from a definite host, but a captured specimen oviposited freely in both *Pseudococcus gahani* Green and *Pseudococcus longispinus* (Targ.) without progeny resulting. Its exact host relationship therefore remains uncertain.

The types of the species herewith described are deposited in the United States National Museum, and the paratypes, except as otherwise noted, are in the collection of the Citrus Experiment Station.

Tetracnemus pretiosus n. sp.

Figures 1 and 2

The insect here recognized as belonging to Westwood's genus agrees closely with original description and figure. The most important discrepancy is that the axillae are only slightly separated. The original description does not consider this structure, but the figure shows the axillae widely separated. There is a possibility, therefore, that the figure overstresses this condition. Until it can be shown that Westwood's insect has the axillae widely separated, it would be better to place the species here described in the same genus; there is even considerable doubt whether the difference in the degree of separation of the axillae should be considered a good generic distinction without other supporting characters.

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* Paper No. 202, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

The male of *T. pretiosus* has the antennal funicle five-jointed, with a long branch on each of the first four joints. The first branch, however, has the appearance of being articulated to the outer apex of the base of the joint. If this is actually the case, it indicates that the first branch is actually the remnant of the second joint of the originally six-jointed funicle, and that the branch, being relatively important, has been preserved, while the basal part of the joint has been practically eliminated by reduction or fusion with the first joint. In the female there are definitely only five funicle joints.

The female of *T. pretiosus* agrees generically in many ways with Girault's genus *Arhopoideus* (Memoirs Queensland Museum, vol. 4, p. 174, 1915), but the head is not longer than wide, the cheeks and scrobes are not especially long, the club is much shorter and only a little wider than the funicle, and the abdomen, at least in contracted condition, is shorter than the rest of the body. Inasmuch as the male of *Arhopoideus* is unknown, it is inadvisable to go farther than to point out the similarity of the genus to *Tetracnemus*.

T. pretiosus is very close to a species of *Tetracnemus* from New Zealand, that was named in manuscript by Dr. L. O. Howard years ago. The male of the New Zealand insect differs from *T. pretiosus* apparently only in having the reticulations of the scutellum a little coarser, or about the size of those of the mesoscutum. The female, however, differs from the same sex of *T. pretiosus,* not only in the same way, but also in having the scutellum brassy green and the mesopleura brown or yellowish brown instead of purple, the scape nearly all yellow, the wings uniformly clear, etc. Adopting Howard's manuscript name for the New Zealand insect, it may be called *Tetracnemus brounii* n. sp.[1]

FEMALE—

Head submenisciform, barely wider than long as seen from in front, widest at lower third of eyes, above that point being broadly rounded and below converging to the rather broad oral margin; as seen from side appearing moderately thick fronto-occipitally, thickest through the middle and with the curvature of anterior surface nearly uniform or only slightly less on lower half. Occiput moderately concave, with the neck inserted near the center. Eyes very slightly longer than wide, nearly circular, touching the occipital margin posteriorly and slightly protuberant at lower end in frontal view of head.

[1] The types of *Tetracnemus brounii* are 5 females and 2 males (holotype ♀, allotype and paratypes) reared from an undetermined species of *Pseudococcus,* at Nelson, New Zealand, by Mr. E. S. Gourlay. The holotype and allotype will be deposited in the U. S. National Museum, and the paratypes returned to Mr. Gourlay.

Frontovertex a little wider than long, almost one-half as wide as head, with the inner orbits of eyes strongly diverging posteriorly and the occipital margin acute. Ocelli large, arranged in an obtuse angle, and with the posterior pair about their own diameter from the eye margins and less than half their own diameter from the occipital margin. Cheeks rather broad and almost as long as one-half the length of head, or almost equaling the diameter of eyes; genal suture absent. Face slightly inflexed and with a rather deep common scrobal cavity, which is slightly narrowed above, reaches a little above the middle of head and lower third of eyes, and is divided in the lower half by a low triangular convex area, with a groove on each side leading to the antennal socket. Antennae inserted moderately close together and very near the oral margin, with the sockets oval and distinctly less than their own length apart. Antennae ten-jointed, with a five-jointed funicle and with the flagellum somewhat clavate-cylindrical.

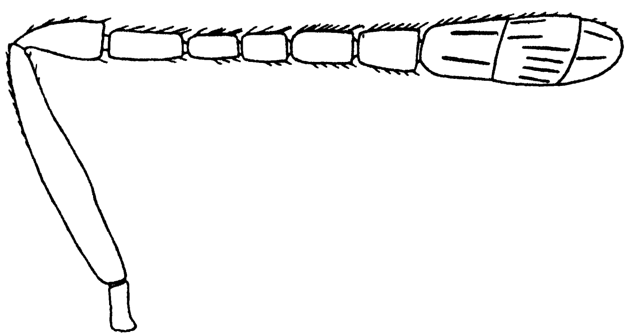

Fig. 1. *Tetracnemus pretiosus* n. sp. Antenna of female.

Scape very slender, moderately long, and surpassing the scrobal cavity by about one-fifth of its own length. Pedicel about thrice as long as thick, distinctly stouter and slightly longer than the following joint. Funicle joints increasing slightly in thickness distad; first joint about thrice as long as thick, the second and fourth about twice as long as thick, the fifth slightly less than twice as long as thick, and the third distinctly the smallest joint and about one-half longer than thick. Club elongate-oval, evenly rounded at apex, distinctly but not greatly wider than funicle and about equaling the combined length of the three preceding joints; its first joint longer than wide and longer than the preceding joint, the second as long as wide, and the third still shorter. Flagellum with fine short antrorse setae, mostly confined to the dorsal and outer surfaces and becoming much finer on the club. Mandibles small, bidentate at apex, with the teeth small, short, and blunt, and the inner one somewhat the longer. Maxillary palpi two-jointed, the first joint as long as thick and the second tapering and about twice as long as the first. Labial palpi about one-half as long as maxillary palpus and composed of one joint.

Thorax about one-third longer than wide, very convex above, and the depth dorsoventrally about two-thirds the width. Pronotum very strongly arcuate and hardly visible in dorsal view. Mesoscutum about

one-half broader across the base than the median length, its basal margin very slightly bisinuate. Axillae rather more than twice as broad as their exterior length, very acute, and nearly meeting medially and their surface plane with scutellum. Scutellum moderately convex, nearly as long as mesoscutum but hardly longer than wide at base, moderately broadly rounded at apex and with the lateral margins abruptly declivous and moderately well elevated but becoming less elevated at apex. Propodeum very short medially, much longer at the sides, convex from side to side, and declivous posteriorly. Spiracles very minute, circular, and placed close to lateral margins of propodeum at the middle and just outside two very fine, parallel longitudinal carinae (the outer carina bisecting the spiracle). Abdomen very strongly compressed, its length to apex of last tergite much less than that of thorax, but length to apex of hypopygium, when abdomen is expanded with ovipositor exserted, more or less equaling or even somewhat exceeding that of head and thorax combined. Hypopygium in expanded condition laminately compressed, with the ovipositor protruded nakedly. Ovipositor sheaths not observable in dry material, but in dissected mounts appear as oval plates, about twice as long as wide, lying just beneath apex of last tergite. Cercal plates placed on each side at base of apical tergite.

Legs of ordinary length and structure, the middle tarsi a little shorter and stouter than hind tarsi, and spur of middle tibiae not quite so long as the first tarsal joint. Wings fully developed and rather narrow in proportion to the length. Submarginal vein not thickened subapically but rather strongly curved; marginal vein between two and three times as long as wide; postmarginal vein practically absent; stigmal vein scarcely longer than marginal and somewhat expanded at apex. Marginal fringe very short and dense. Discal setae beyond speculum short, fine, and rather dense. Speculum in breadth equaling the length of stigmal vein, not reaching to posterior margin, bounded on its proximal margin above by the venation, and after passing beyond bend in submarginal separated from basal area by only two or three rows of very fine weak pale-colored setae. Basal area bare except a row of fine setae close to submarginal vein. Costal cell with rather dense fine setae, which become weaker and sparser along the vein and toward the base of cell. Hind wings with a longer marginal fringe than fore wings and with the costal cell extremely narrow.

Head and mesoscutum shining and finely scaly-reticulate, with the areoles becoming longitudinal on sides of face. Scrobal impression polished. On the cheeks the reticulations become faint, and toward the occiput and on the postocular region they are replaced with fine lineolations. Frontovertex with a few scattered fine punctures. Axillae and scutellum finely and delicately tessellate. Propodeum polished. Mesopleura finely lineolate-tessellate. Abdomen finely tessellate, but first tergite toward base and the hypopygium polished. Cheeks, frontovertex, mesoscutum, and scutellum with fine, short, moderately numerous, dark-colored and inconspicuous hairs, the scutellum without enlarged hairs at apex. Eyes with very short, fine, erect hairs.

Head and thorax rather dark brassy green, with the scrobal impression blue and the axillae and scutellum dark purple blue. Cheeks posteriorly and the postocular region bluish. Pleura of thorax and the abdomen blue, the mesopleura and venter with a purple luster, the first tergite, however, brassy green. Antennae piceous, but basal half of scape, excluding radicle joint, dull yellow. Legs yellow; the coxae, trochanters, and femora pale lemon yellow, the tibiae and tarsi more brownish yellow, and last joint of tarsi fuscous. Wings slightly dusky hyaline, with the speculum clearer than other parts. Basal half of submarginal vein yellowish, the remainder of venation fuscous.

Measurements in millimeters as follows: length of body, (0.917 to) 1.48; length of head, 0.406; width of head, 0.475; width of vertex at anterior ocellus, 0.212; thickness of head fronto-occipitally, 0.371; length of antenna, 0.956; width of mesoscutum, 0.476; length of fore wing, 1.084; width of fore wing, 0.515.

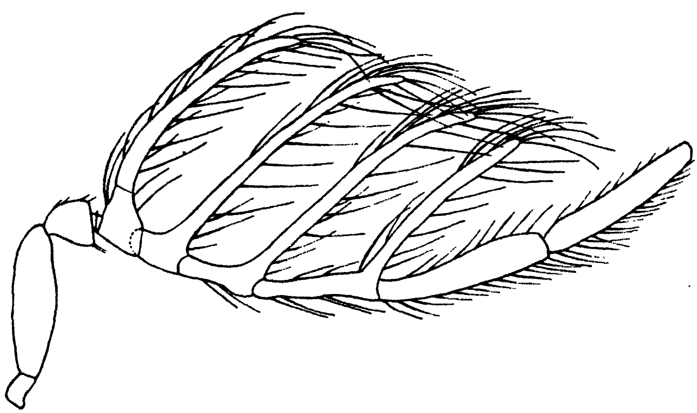

Fig. 2. *Tetracnemus pretiosus* n. sp. Antenna of male.

MALE—

Head irregularly submenisciform, rather thin fronto-occipitally and thickest through the middle of eyes; as seen from in front somewhat broader than long, broadest through the eyes, and with the cheeks strongly and somewhat arcuately converging below. Eyes rather small, very slightly longer than wide, convex, and rather strongly protuberant. Frontovertex about twice as broad as long, more than one-half as broad as whole head, moderately convex from side to side and with the occipital margin acute. Ocelli in a very obtuse angle, the anterior one placed at the center of frontovertex, and the posterior pair almost touching the occipital margin and placed rather more than one-half their own diameter from the eye margins. Cheeks as long as the lesser diameter of eyes, rather convex, with a slight indication of a longitudinal ridge subposteriorly, and without a genal suture. Face with a large, moderately deep, common scrobal cavity, reaching above to anterior margin of frons, and divided lengthwise for almost its entire length by a low rounded ridge which broadens toward the antennal sockets. Antennae inserted about half-way between ocular line and oral margin, with the sockets placed about their own width apart and at practically the same distance from oral margin. Antennae

eight-jointed. Scape slender, subfusiformly compressed, and surpassing the scrobal cavity. Pedicel small, or scarcely longer than thick. Funicle five-jointed; joints 1 to 4 each with a long slender ramus inserted above at apex, the rami all about equal in length; the joints, excluding rami, increasing greatly in length distad, the first broader than long, the second slightly longer than wide, the third about twice as long as the second, the fourth about three times as long as the second, and the fifth slender, terete, and a little longer than the fourth. Club entire, very elongate-oval, considerably thicker than the preceding joint and about as long. Rami with numerous long spreading hairs, the funicle joints otherwise and the club with similar but shorter hairs.

Thorax similar to that of female, but much less convex longitudinally, and with the axillae indistinct. Abdomen about two-thirds as long as thorax and strongly compressed. Cercal plates and vibrissae inserted at the middle on each side. Aedeagus in dry specimens usually protruded and strongly curved downward. Legs practically as in female. Wings similar but the fore pair considerably broader in proportion to length.

Frontovertex and mesonotum rather dull, somewhat roughly and very finely scaly-reticulate, and with the scutellum somewhat more finely sculptured and rather more shining than the mesoscutum. Face and cheeks shining, the scrobal cavity and clypeal margin below antennae polished, the face otherwise finely reticulate with the areoles for the most part somewhat longitudinally lengthened. Cheeks posteriorly and the postorbital region very delicately lineolate or almost polished. Pleura shining and finely reticulate, the propleura and prepectus distinctly sculptured, and the mesopleura more delicately reticulate, with areoles longitudinally lengthened. Propodeum polished. Abdomen very finely tessellate and rather dull. Pubescence as in the female.

Head and thorax very dark green, the mesoscutum appearing almost piceous in some aspects. Face and cheeks brilliant brassy green. Scutellum nearly as dark as mesoscutum but with a dark reddish and purple instead of a dull green luster. Propodeum somewhat bluish green with a brassy luster. Mesopleura mostly dark blue or purple blue. Abdomen piceous, mostly without a metallic luster, but sometimes purplish on the sides especially at base. Antennae piceous, but the scape yellow except its apical fourth and the radicle joint. Front and middle legs dull yellow with the front tarsi more or less infuscated. Hind coxae bluish, the femora, except base and sometimes beneath, tibiae, except sometimes beneath, and hind tarsi fuscous, the hind legs otherwise yellow. Wings clear hyaline, the veins fuscous.

Measurements in millimeters as follows: length of body, (0.796 to) 1.25; length of head, 0.408; width of head, 0.490; width of vertex at anterior ocellus, 0.290; thickness of head fronto-occipitally, 0.238; length of antenna, 0.966; width of mesoscutum, 0.479; length of fore wing, 1.172; width of fore wing, 0.573.

Described from 2 females, 7 males (holotype ♀, allotype, and paratypes) reared in January, February, and March, 1928, from *Pseudo-*

coccus gahani Green, collected at Sydney, New South Wales (H. Compere) ; and 15 females, 27 males (paratypes) reared from the same host in the propagating cages at Riverside, California, in April and May, 1928.

Anusoidea comperei n. sp.

Figures 3 and 4

This species differs from *Anusoidea aurciscutellum* Girault in having the thorax mainly piceous without a purple luster, the mesopleura entirely dark, and only the apex of front and middle tibiae, with their tarsi, yellowish. The color of the scutellum is also apparently redder. The general form and habitus of this genus in the female sex is superficially like *Homalotylus* Mayr but it differs greatly in the venation, the very large Cerapterocerus-like antennae, and in many other details, so that the resemblance to *Homolatylus* is merely an example of homoplasmy.

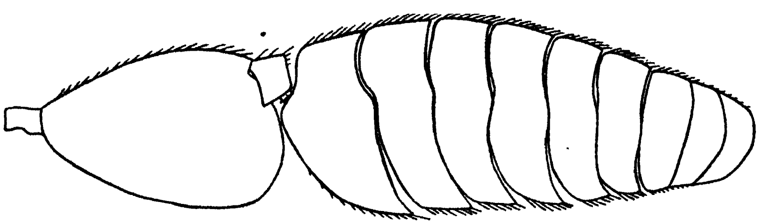

Fig. 3. *Anusoidea comperei* n. sp. Antenna of female.

FEMALE—

Head menisciform, slightly longer than wide, moderately thick fronto-occipitally, thickest approximately at middle, strongly rounded on the sides and gently rounded on the dorsal margin. Occiput only slightly and uniformly concave, with the neck inserted at the center. Eyes large, distinctly less than twice as long as broad, and oval, except that the posterior orbits are practically straight. Inner orbits only slightly diverging anteriorly as seen in dorsal view of head, yet strongly diverging at extreme lower ends. Frontovertex much longer than wide, in ocellar region about one-half as wide as either eye, continuous below with face, and with the occipital margin rather sharp. Ocelli in an acute angle, the posterior pair placed about one-half their own diameter from the eye margins and remote from occipital margin. Cheeks moderate in length, rather less than one-third as long as eyes, and with the genal suture very fine but distinct. Postocular space rather narrow and more narrowed above, the summit of eyes touching occipital margin. Face rather depressed and with distinctly separated scrobes. Antennal sockets placed rather close together, almost at the oral margin, and separated by a well elevated, convex, longitudinal ridge, which is not at all narrowed above. Antennae very large, foliately expanded and nearly as long as entire body. Scape large, very broadly and laminately expanded, pyriform in outline, nearly as

thin on dorsal as on ventral margin, with the apex broadly and truncately rounded and the ventral margin only slightly convex. Pedicel very small but laminate, and having the dorsal margin abruptly bent downward in a right angle at the middle, so that the apex appears to be on the ventral margin. Flagellum very broad and laminate, broadest a little before the middle, then tapering to the broadly rounded apex. First funicle joint largest and longest, yet the third slightly the broadest of all, the third to sixth about equal in length but successively narrowing distad. Club about as long as wide at base, somewhat narrowing to the broadly rounded apex, and with the three rather obscure joints becoming successively shorter distad. Mandibles small, bidentate, the teeth acute and slightly unequal. Maxillary palpi two-jointed, slender, the apical joint somewhat more than twice as long as thick and about one-half as long as the basal joint. Labial palpi similar to the maxillary pair but much shorter, the apical joint not much longer than thick.

Thorax about one-half longer than wide, considerably wider than deep dorsoventrally and gently convex above. Pronotum short and arcuate. Mesoscutum about twice as broad as long, and having the posterior margin between tegulae practically straight. Axillae rather large, each nearly twice as broad as long on outer edge, the inner ends very acute and contiguous, and the surface plane with scutellum. Scutellum large, depressed, about as long as wide, moderately acute at apex, and having the sides convexly arcuate to a slight degree, abruptly declivous and moderately well elevated. Propodeum very short medially but having the usual length at sides, its surface moderately declivous medially, and subdepressed at the sides, except on posterior margin which is narrowly declivous. Propodeal spiracles small, circular, and about equally distant from anterior and lateral margin of the segment. Metapleura very narrow. Abdomen about two-thirds as long and not quite so wide as thorax, triangular as seen from above, and about one-third longer than wide at base. Tergum deeply concave and the venter rather strongly compressed. Cercal plates retracted within the concavity of tergum close to the base of abdomen and mainly concealed. Ovipositor entirely enclosed by vomeriform apical ventrites.

Legs slender and about as long as in *Homalotylus;* hind tibiae and tarsi very slender; middle tibiae and tarsi stouter, the tarsi slightly tapering toward apex and the tibial spur almost as long as the basitarsus. Wings more than twice as long as wide and reaching well beyond apex of abdomen. Marginal fringe short and rather dense. Discal setae fine and dense in area below that portion of venation from proximal end of thickened part of submarginal vein to apex of stigmal vein. This densely pubescent area followed by a narrow, strongly arcuate band, where the setae are colorless. Apex of wing beyond arcuate band moderately setose. Basal area almost entirely bare except one row of rather coarse setae beneath submarginal vein. Speculum very narrow and very oblique, not quite reaching to base of stigmal vein and barely reaching beyond the middle of disk, where it is well separated from the basal area. Area between speculum and venation with rather coarse setae. Costal cell rather narrow and with

only one row of fine setae, except toward the apex where there are two rows. Submarginal vein slightly sinuate and thickened in its apical fifth. Marginal vein elongate or about six or seven times as long as thick. Postmarginal vein subobsolete. Stigmal vein about equal to marginal, almost straight, slender, hardly appreciably enlarged at apex, and forming an angle of about 40° with costal margin. Submarginal vein with about fourteen enlarged setae, the longest of which only slightly exceed the width of the costal cell. Setae on marginal vein numerous and similar to those between speculum and venation. Hind wings with the costal cell extremely narrow and not reaching to the hooklets, the marginal fringe of the posterior margin about twice as long as fringe of fore wings, and the disk bare at base almost as far distad as the bend in the vein. Remainder of disk with moderately dense setae which become subobsolete at the extreme apex.

Face and frontovertex moderately dull and with fine, dense, shallow, malleate punctures. Occiput with transverse lineate reticulations. Mesoscutum shining, metallic, very minutely and delicately reticulate. Axillae and scutellum opaque from an extremely fine dense shagreening. Pleura and abdomen finely reticulate and shining. Head almost bare, except a few extremely short fine setae on the postocular region and a row of equally minute, glistening white setae on face close to margin of eyes. Mesoscutum with fine, appressed, white setae, moderately close and becoming obsolete on posterior border. Scutellum with rather sparse, short, black setae, a pair of long black setae at apex and two pairs of subapical setae, which are about one-half as long as the apical pair.

Head dark orange brown, becoming more or less piceous on face, and orange ferruginous on the upper half of occiput. Thorax and abdomen piceous, the pronotum somewhat brownish, the mesoscutum shining with a slight plumbeous luster, the axillae very dark reddish brown, and the scutellum orange red. Antennae entirely piceous and shining. Legs piceous, the coxae, trochanters, and base of femora of front and middle legs and apex of middle femora creamy white, the apex of front and middle tibiae, with their tarsi, yellowish, and the apex of hind tibiae and hind tarsi brownish. Wings hyaline, the fore wings each with a broad fuscous band across the middle, exactly covering the more densely setose area of disk, the distal margin of band strongly convex and the proximal margin somewhat obliquely transverse. Venation piceous, but the submarginal vein, except the thickened apical part, brown.

Measurements in millimeters as follows: length of body, (1.70 to) 1.85; length of head, 0.649; width of head, 0.594; width of vertex at posterior ocelli, 0.149; thickness of head fronto-occipitally, 0.323; length of antennae, 1.61; greatest width of antenna, 0.418; width of mesoscutum, 0.568; length of fore wing, 1.61; width of fore wing, 0.608.

MALE—

Head submenisciform, about as broad as long, well rounded on the sides and above, and moderately thick fronto-occipitally. Face somewhat reflexed, the frons not prominent. Occiput moderately concave, with the neck inserted near the center. Eyes rather small, only a little

longer than broad, and somewhat protuberant. Cheeks about three-fourths as long as eyes, convergent in frontal view toward the rather narrow mouth, and with the outer margin slightly discontinuous with eyes. Frontovertex a little broader than long, slightly widening anteriorly, the posterior part nearly twice as wide as the eye. Ocelli large, approximately in a right angle, the posterior pair a little more than their own diameter from the eye margin and slightly closer to the acute occipital margin. Face with a large shallow common scrobal cavity, descending considerably below the antennal sockets and divided by a very low longitudinal ridge, which extends upward hardly above the sockets. Antennal sockets situated close together on the ocular line and remote from oral margin. Antennae filiform and almost as long as body. Scape compressed, but not expanded, the ventral edge thin, with radicle excluded about four times as long as wide, and including radicle about as long as pedicel and first funicle joint combined. Pedicel slightly longer than thick. Flagellum slender and filiform. Funicle joints all much longer than thick, the distal joints slightly shortening, with the sixth about two and one-half times longer than thick. Club entire, long, tapering, acuate at apex, and almost as long as the last two funicle joints combined. Flagellum provided with numerous, uniformly distributed, short, antrorse setae.

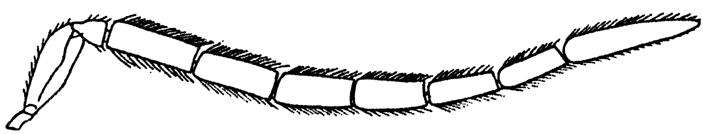

Fig. 4. *Anusoidea compersi* n. sp. Antenna of male.

Thorax much as in the female, but mesoscutum more convex, with its posterior margin slightly angulate medially, and the axillae slightly separated. Abdomen depressed, about as wide as thorax and three-fourths as long, or in dry specimens much shorter than thorax, triangular in form, and acute at apex. Cercal plates retracted to about the basal fourth in dry specimens, or in less contracted specimens to about the middle. Legs practically as in female. Wings shorter and broader than in female, the disk beyond speculum with uniform moderately dense setae. Speculum moderately wide, not quite reaching to stigmal vein and interrupted below, the setae on its proximal margin a little coarser than elsewhere. Base of disk more sparsely setose than the middle with a hairless band on posterior margin of wing and an enclosed triangular hairless area. Costal cell with three complete rows and an incomplete row of setae. Submarginal vein very slightly thickened in the apical fourth; marginal vein about three times as long as wide; postmarginal vein indistinct and spur-like; stigmal vein about one-fourth longer than the marginal and scarcely thickened at apex. Hind wings with the discal setae moderately dense and uniformly distributed, except in a small bare area at base.

Frontovertex, mesoscutum, axillae, and scutellum with a very minute, opaque or subopaque shagreening, which is duller on the scutellum. Under low magnification this sculpture appears granular

tessellate, but when highly magnified it appears puncto-tessellate, with the tessellations irregular in shape, usually more or less longitudinally lengthened, and becoming a little coarser on scutellum. Lower part of face, cheeks, and pleura much more shining than the dorsum, and finely reticulate. Abdomen shining. Face with rather sparse, fine, appressed, glistening white setae. Frontovertex with short erect black setae. Eyes with a fine, very short, rather dense pile. Pubescence of thorax about as in female, except that the setae of mesoscutum are whitish only at the sides, and, therefore, much less conspicuous.

Body piceous or black, non-metallic, the face sometimes somewhat brownish, the prepectal plates pale brown. Antennae black with black setae, but the scape yellowish beneath toward base. Front and middle legs very pale brownish yellow, the coxae brown or piceous and middle tibiae on basal half more or less dusky. Hind legs entirely brownish piceous, sometimes a little paler on femora. Wings entirely clear hyaline, the venation piceous.

Measurements in millimeters as follows: length of body, (1.23 to) 1.59; length of head, 0.447, width of head, 0.505; thickness of head fronto-occipitally, 0.254; width of vertex at anterior ocellus, 0.247; width of mesoscutum, 0.540; length of antenna, 1.52; length of fore-wing, 1.41; width of fore wing, 0.649.

Described from 3 females, 7 males (holotype ♀, allotype, and paratypes) from Sydney, New South Wales (Compere). The holotype was reared December 4, 1927, from an undetermined mealybug. The remaining specimens are the offspring of this female, propagated on *Pseudococcus gahani* Green. The males were reared January 2–7, 1928, and the female paratypes were obtained February 10, 1928, after the parent had been mated with her own male offspring.

Anarhopus n. gen.

Figure 5

In Girault's table (Mem. Queensland Mus., vol. 4, p. 179) *Anarhopus* runs to *Arhopoideus* Girault, from which it differs in having the antennae large, with the flagellum compresso-clavate, the funicle joints increasing in width distad, the fifth joint distinctly wider than long, the club broadly rounded at apex, concave on inner surface, and about one-half as long as funicle, the fore wing with a broad cross-band, the abdomen strongly compressed throughout, considerably shorter than thorax and with the ovipositor enclosed by the ventrites, etc. In Mercet's table it runs out at couplet 21, as the marginal vein is distinctly longer than wide and the ovipositor is concealed.

Genotype:

Anarhopus sydneyensis n. sp.

FEMALE—

Head as long as wide, submenisciform, in frontal view well rounded above and on sides, but with the cheeks converging somewhat to the

rather broad oral margin and discontinuous with outline of eyes. Occiput deeply concave longitudinally so that the eyes in dorsal view extend much farther back on each side of head than does the very acute occipital margin of vertex. Neck inserted near center of occiput. Eyes moderate in size, nearly circular, or only a little longer than wide, and with the inner orbits appearing almost parallel in dorsal view of head, although appearing to diverge slightly at anterior ends in frontal view. Postorbital region moderately wide below and becoming extremely narrow above posteriorly where the eyes do not quite touch the occipital margin. Cheeks very large and broad, not quite so long as diameter of eyes and with the genal suture obsolete. Frontovertex broad and covering much more than one-third but not quite one-half the width of head. Ocelli in a somewhat obtuse angle, the lateral pair about their own diameter from the eye margins and about equally distant from occipital margin. Face joining with frons in a broad curve and with a large common scrobal cavity. The latter rather deep, with long sloping margins on sides and above, and reaching dorsally above lower ends of eyes by approximately one-fourth their length. Antennal sockets placed close together, or not quite their own length apart, almost on the clypeal margin, and separated by a short low longitudinal ridge, which does not extend above the sockets. Antennae ten-jointed, the flagellum compresso-clavate with a five-jointed funicle. Scape rather slender, compressed, fusiform, and excluding the radicle about as long as the next three joints combined. Pedicel twice as long as thick and about as long as the following joint. First three funicle joints subequal in length, the next two becoming successively shorter, all increasing gradually in width distad, the first about one-half longer than wide, the third about as long as wide, and the fifth about one-third wider than long. Club about three times as long as wide, about one-half as long as the funicle, and as wide as the preceding joint. Its apex broadly and nearly evenly rounded, and its inner surface deeply concave. The sutures between the three joints much more distinct on the convex outer surface of the club. First suture strongly arcuate, the second very strongly oblique. Greatest length of first joint about two-fifths that of entire club. Second joint about four to five times longer across superior margin than below. Third joint comparatively small and oblique. Pedicel and funicle joints densely covered with short, erect, spiny setae, the club on convex outer surface with similar smaller setae, which become evanescent toward apex. Each joint of the club with about six fine, linear sensoria.

Thorax convex, robust, about two-thirds longer than wide, and but slightly less deep dorsoventrally than wide. Collar of pronotum very narrow and arcuate. Mesoscutum large, convex, about one-third wider than long, and with the hind margin nearly straight. Axillae a little more than twice as wide as long exteriorly, very acute and practically meeting medially, their disks plane with scutellum. Scutellum about two-thirds as long as mesoscutum, the sides slightly arcuately convergent to the bluntly rounded apex, the disk depressed, and the margins rather well elevated and very abruptly declivous. Propodeum long at the sides, but at the middle shortened about one-half, rather

strongly convex from side to side and obliquely declivous toward the rear. Propodeal spiracles very minute, circular and placed on the lateral margin remote from anterior margin. Abdomen strongly compressed throughout, about three-fourths as long as thorax, its apex laminately compressed with the last ventrite surpassing apex of tergum. Ovipositor entirely enclosed by ventrites. Cercal plates and vibrissae not visible in dry specimens. Legs ordinary and moderately long; middle tarsi stouter than hind pair and slightly tapering; spur of middle tibiae almost as long as the basitarsus. Wings fully developed, infuscated from marginal vein distad, but becoming paler at apex. Marginal fringe rather dense and short. Discal setae dense in infuscated area and becoming a little weaker and sparser toward apex. Clear basal area of disk almost free from setae except in the space beyond speculum on posterior margin, there being one row of about 7 to 9 setae below submarginal vein and one oblique row of about 4 or 5 smaller setae across disk from middle of submarginal vein.

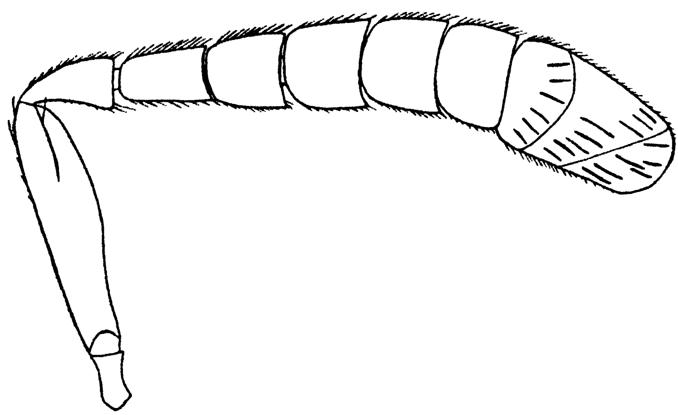

Fig. 5. *Anarhopus sydneyensis* n. sp. Antenna of female.

Speculum, therefore, weakly differentiated, reaching to stigmal vein and becoming very broad and open below. Costal cell rather wide and with two incomplete and irregular rows of setae. Submarginal vein not thickened distad and armed with about 15 bristle-like setae which are almost as long as width of costal cell. Marginal vein about twice as long as wide and armed with numerous fine setae. Postmarginal vein very short. Stigmal vein about as long as marginal and postmarginal veins combined, a little curved and slightly widened at apex. Hind wings with the vein rather strongly arcuate in the basal half, the costal cell extremely narrow, the discal setae moderately dense on apical half of disk, and with the marginal fringe nearly twice as long as that of fore wings.

Head finely puncto-reticulate with the cheeks and scrobal cavity much smoother. Frontovertex with sparse, fine, shallow pin punctures. Mesoscutum very finely scaly-reticulate and with sparse shallow pin punctures. Axillae minutely tessellate. Scutellum with very fine and dense, thimble-like punctures. Propodeum and metapleura polished,

the former with two fine parallel longitudinal carinae at middle, placed about their own length apart, and with two fine parallel carinae running close together on each side from spiracle to hind margin. Mesopleura finely reticulato-lineolate. Abdomen smooth and shining. Eyes and frontovertex with about equally fine, very short, erect and rather sparse setae. Clypeal margin and prominence between antennae with somewhat longer setae. Mesoscutum with sparse, short retrorse setae, which are pale but not conspicuously whitened. Scutellum with sparse inconspicuous setae, the two pairs at apex erect but only slightly enlarged.

Coloration strongly metallic but with the luster not brilliant except on the smoother parts.

MALE—

Not known.

Anarhopus sydneyensis n. sp.

FEMALE—

Head and thorax metallic green with a brassy luster, the scutellum dark green. Propodeum with a brilliant brassy and reddish luster. Cheeks strongly brassy. Mesopleura bluish at posterior end. Abdomen rather brilliantly metallic and mainly steel blue and purple. Eyes very dark chestnut red. Antennae black, the scape with a greenish luster on the outer surface and with a longitudinal white streak on inner dorsal margin, not quite attaining the apex. Coxae, front femora except apex, and hind femora metallic greenish. Apex of front femora and tibiae, and the front tarsi brown, the tibiae otherwise piceous. Middle femora piceous but becoming more or less pale brown at apex and on anterior margin of apical half. Middle tibiae, spurs, and basal third of hind tibiae white, but the middle tibiae sometimes more or less ferruginous brown especially toward apex. Hind tibiae otherwise piceous. Middle and hind tarsi ferruginous brown, with the apical joint piceous. Fore wings clear hyaline at base but with a well infuscated cloud distad from level of marginal vein. Basal margin of cloud very convex. Apex of wing becoming broadly much paler but not entirely clear. Hind wings clear at base and becoming abruptly somewhat dusky on apical half. Submarginal vein dusky testaceous, the marginal and stigmal veins piceous.

Measurements in millimeters as follows: length of body, (1.61 to) 1.69; length of head, 0.577; width of head, 0.564; width of vertex at anterior ocelli, 0.247; thickness of head fronto-occipitally, 0.304; length of antenna, 1.403; greatest width of antenna, 0.158; width of mesoscutum, 0.568; length of fore wing, 1.395; width of fore wing, 0.592.

Described from 4 females (holotype and paratypes), collected near Sydney, New South Wales (H. Compere). Holotype captured on orange tree at Wahroonga, December 8, 1927, and the paratypes reared December 1–10, 1927, from mealybug material collected in citrus orchard at Warrawee.

MORPHOLOGICAL STUDIES OF THE HEAD AND MOUTHPARTS OF THE MATURE CODLING-MOTH LARVA CARPOCAPSA POMONELLA (LINN.)

BY

ALONZO W. LOPEZ

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INTRODUCTION

Although the amount of literature relating to the control and habits of the codling moth is enormous, apparently very little work has been done on the morphology of this insect. In fact, the only papers found were one by Bordas (1910), entitled Les Glandes Céphaliques des Chenilles de Lépidoptères, dealing with the silk and mandibulary glands, and one by Montgomery (1900), entitled On Nucleolar Structures of the Hypodermal Cells of the Larva Carpocapsa.

"Caterpillars are remarkable for their standardization of structure. In none of the other large groups of insects is there such uniformity in fundamental organization as in the larvae of the Lepidoptera" (Snodgrass, 1928, p. 131). A great deal of work has

been done on the morphology of various caterpillars, that of Lyonnet (1762) perhaps being the first. The larva of *Bombyx mori* Linn., the silkworm, has been the subject of extensive morphological work (Grandi, 1922), and since caterpillars are so standardized, much of the information already obtained from other species can be applied to *Carpocapsa pomonella.*

The lack of specific morphological work on this species is the more surprising in view of the facts that it has been a pest for hundreds of years, and that material can be obtained in any quantity desired.

ACKNOWLEDGMENTS

This work was undertaken at the instance of Dr. R. H. Smith of the Citrus Experiment Station, University of California, Riverside, California. I take this opportunity to thank him for the many helpful suggestions as to collection, preservation of material, and technique that he offered when the work was first started at the Experiment Station.

I am principally indebted to Dr. Stanley B. Freeborn for suggestions, corrections, and general supervision of the work. Professor E. O. Essig has also been of very great assistance to me through his many suggestions as to methods of procedure. Professor W. B. Herms has been very kind in permitting the use of laboratory equipment.

I am grateful to Dr. S. F. Light for correction of the manuscript, and to Mr. J. F. Lamiman for helpful suggestions.

MATERIAL AND METHODS

The bulk of the larvae were taken from under burlap bands on apple trees in the Yucaipa district of San Bernardino County, California, during the months of July and August, 1928. A few were obtained from the Sebastopol district of Sonoma County, California.

The larvae were killed in boiling water and placed in 70 per cent alcohol. A slight distortion occurred as a result of boiling. The specimens from which superficial drawings were to be made were pinned to a cork pad and submerged in water. A binocular microscope was used, and all outlines were made with a camera lucida, corrected for distortion, the details being supplied by higher magnification. Best results were obtained with the material for dissection by allowing

it to stain overnight or longer in borax-carmine after incisions had been made in the head capsule and abdomen to allow the stain to penetrate. Borax-carmine did not overstain the material even after a long period of immersion.

Some specimens of overwintering larvae taken from a mass of pupal material in December were placed in water and examined alive under the binocular. Much of their fat had been consumed, making them somewhat transparent. Some of the superficial nerves of the dorsal surface could be plainly seen, as well as parts of the tracheal system.

In making the dissections for locating the various internal structures, the dorsal surface of the head capsule was removed with dissecting needles and the thorax and abdomen were opened along the dorso-meson by breaking the tissues apart with the needles. The larvae were then pinned out flat on a piece of cork under water.

The silk and mandibulary glands and the central nervous system stained a pronounced crimson, and were easily located. One of the greatest difficulties encountered in dissection was the presence of a great abundance of adipose tissue, or fat. In teasing this fat away, connections were often broken, this being especially true of the mandibulary glands which lie close to the surface.

Drawings of the more minute structures were made from material mounted in balsam or glycerine jelly, the compound microscope being used.

The tentorium could easily be seen after a head had been boiled in caustic potash for a short time. It was also worked out by dissection of a preserved head.

EXTERNAL ANATOMY OF THE HEAD

The head (figs. 1, 2, 3) is the smallest major division of the body. It is a non-wrinkled, pale brown region, which from a lateral or ventral aspect is oval in outline, while from a dorsal aspect, it is spherical. The head averages about 1.5 mm. in length, and an equal distance in width.

Dorsal aspect (fig. 1).—Along the dorso-meson, or vertex, is a distinct median suture (*ms*) which turns downward on the face and divides into the two epicranial sutures (*es*), which extend anteriorly to the epicondyles (fig. 10, *ec*), or dorsal articulations of the mandibles.

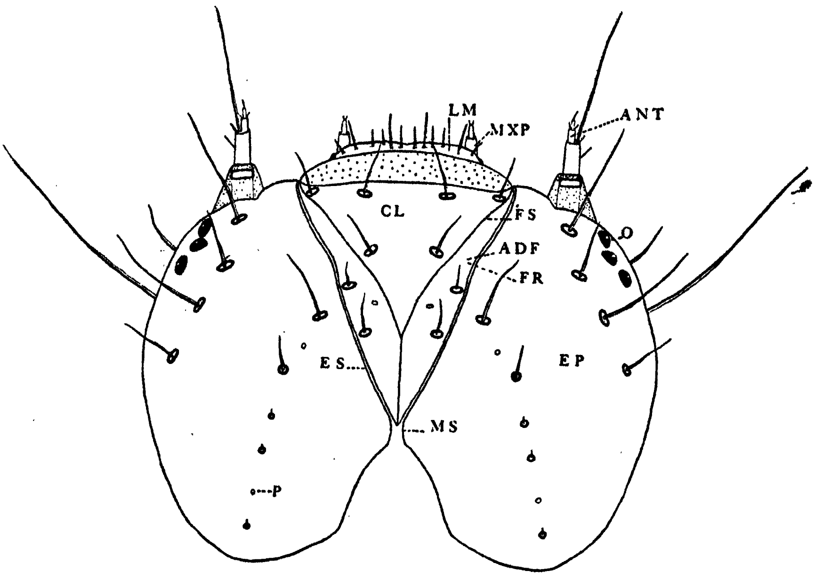

Fig. 1. Dorsal aspect of head. The membranous areas in both figures are stippled.

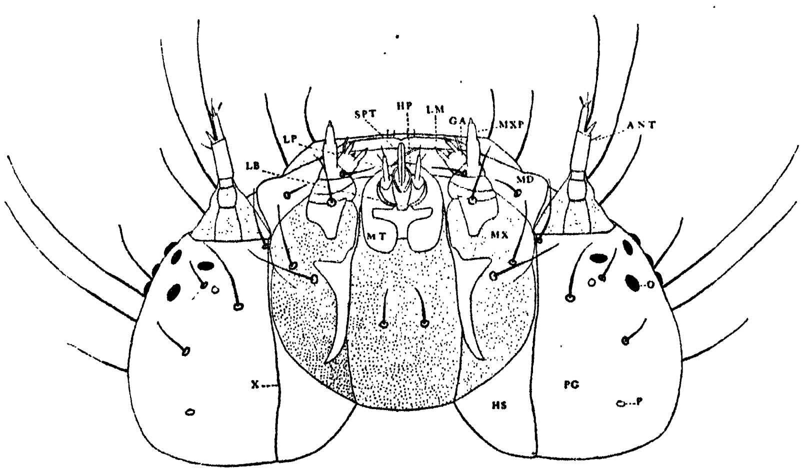

Fig. 2. Ventral aspect of head. Spinneret normally extends ventrally instead of anteriorly.

adf, "adfrons"; *ant*, antenna; *cl*, clypeus; *ep*, epicranium; *es*, epicranial suture; *fr*, frons; *fs*, fronto-clypeal or epistomal suture; *ga*, galea; *hp*, hypopharynx; *hs*, hypostoma; *lb*, labium; *lm*, labrum; *lp*, labial palpus; *md*, mandible; *ms*, median suture; *mt*, mentum; *mx*, maxilla; *mxp*, maxillary palpus; *o*, ocellus; *p*, puncture; *pg*, postgena; *spt*, spinneret; *x*, hypostomal suture.

These sutures form the lateral boundaries of the combined frons and clypeus and separate this area from the epicrania (*ep*). The epistomal or fronto-clypeal suture (*fs*), that normally follows a transverse course from one epicondyle to the other has, in lepidopterous larvae (according to Snodgrass, 1928) arched into the area normally assumed by the frons. This departure carries the clypeus (*cl*) toward the vertex and forces the frons (*fr*) into two small lateral areas (the "adfrons" *adf* of Forbes, 1910, and of Imms, 1925) and a small median area at the branching of the epicranial sutures. Normally there are four setae and two punctures (*p*) on the frons. The punctures appear as circles with reddish periphery. The internal view of this area shows a well developed epistomal ridge (fig. 15, *er*) (so designated by Snodgrass because it carries the articulations of the anterior arms of the tentorium). At the apex of its arch it is closely fused with the median suture, the true arms of which are relegated to a position of secondary notice, appearing interiorly as faint lines.

Clypeus.—The area within the arch of the epistomal or fronto-clypeal suture (*fs*) is the clypeus (*cl*) of Snodgrass (1928), the "front" of Forbes (1910), and of Peterson (1912), and the "frons" of Crampton (1921). At the anterior border of the true clypeus is a membranous area, the "clypeus" of Crampton and Peterson. The true clypeus usually bears six setae of varying lengths, and the epicrania each bear eight normal setae, three very short or rudimentary ones, and two punctures.

Ventral aspect (fig. 2).—The labium (*lb*) occupies the central portion of the ventral surface of the head, with the antennae arising from pits at the anterior borders of the postgenae (*pg*). On each side is the hypostoma (*hs*), a posterior median part of the postgena separated from the more lateral postgenal regions by the hypostomal suture (*x*). Normally four setae arise from the postgenae, and two punctures occur there.

Setae.—The setae arise from paler circular areas having a darker border. They may not always be constant in number and location, for one specimen was found with an additional seta on the epicranium.

Eyes.—The simple eyes (fig. 3, *o*) consist of two groups of six pigmented ocelli each, five of which are in a semicircle, the sixth lying anterior to and below the arc formed by the others. The two groups, viewed from the lateral aspect, are situated on the sides or genae of the head, slightly ventrad.

Antennae.—Each antenna (figs. 3, 4, *ant*) arises from a pit (fig. 10, *ap*) in the head capsule. Viewed from the frontal aspect, the pits are closed mesad by the bases of the mandibles and extend laterad almost to the ocelli.

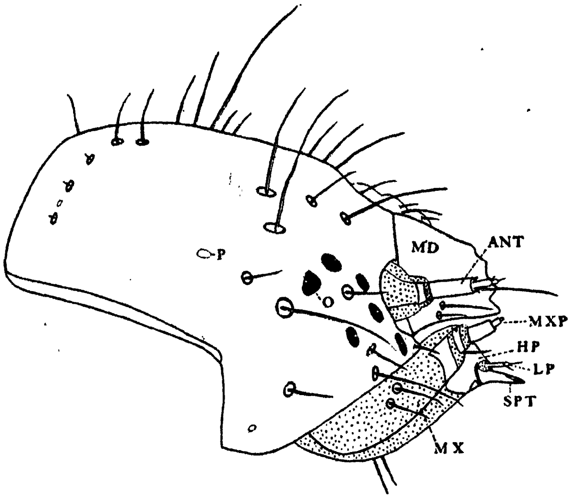

Fig. 3. Lateral aspect of head, mandibles extended.

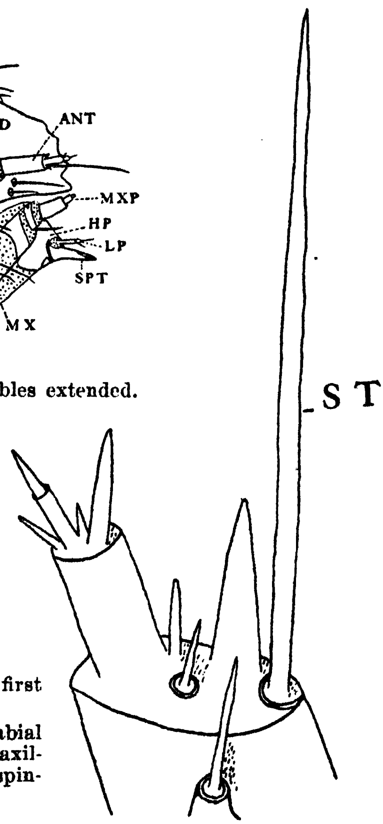

Fig. 4. Antenna distally from tip of first segment.

ant, antenna; *hp*, hypopharynx; *lp*, labial palpus; *md*, mandible; *mx*, maxilla; *mxp*, maxillary palpus; *o*, ocellus; *p*, puncture; *spt*, spinneret; *st*, sensillum trichodeum.

A membrane extends up around the bases of the antennae which are three-segmented with all but the first being comparatively minute. Proximad of the tip of the first segment is a small seta (fig. 4) and at the distal end of the segment is a very long hair, or sensillum trichodeum (*st*, Comstock, 1924, p. 130). Also at the distal end of the first segment are three sensory structures, which may be sensilla basiconica. The one mesad of the sensillum trichodeum is about twice as long and a little wider than the others. The second sensory structure lies near the base of the second segment, and the third arises on

the upper side of the segment. At the distal end of the second segment there are also three sensory structures, the outside one being the largest, about one and one-half times the length of the third segment. The antennae are terminated distally by a projection from the third segment. The length of the antennae from the base of the first segment to the distal extension of the third segment is about 0.2 mm.

MOUTHPARTS AND INTERNAL ANATOMY OF THE HEAD

The mouthparts consist of the labrum, labium, maxillae, and mandibles.

Labrum.—The labrum (figs. 5, 6, 10, *lm*) is a simple, bilobed plate separated from the clypeus by the membranous area mentioned in

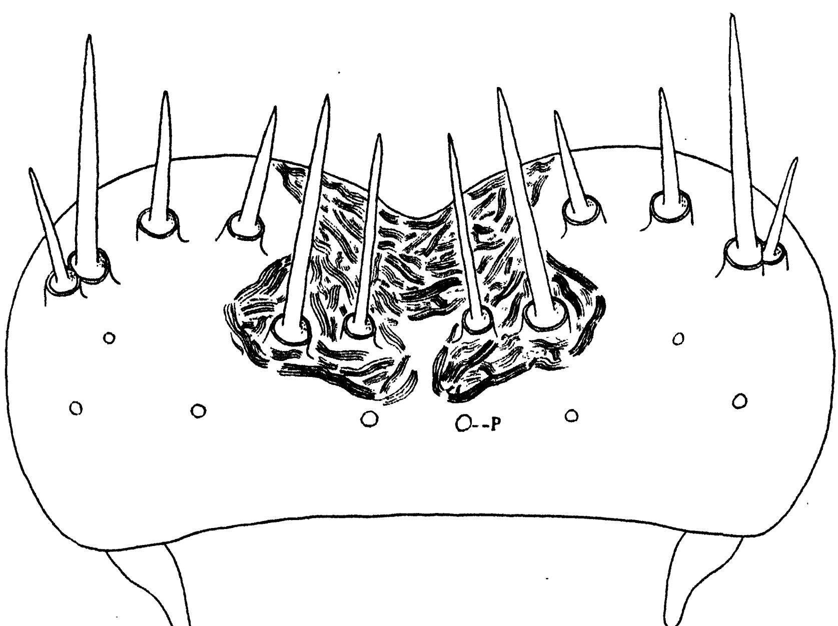

Fig. 5. Dorsal aspect of labrum. *p, puncture.*

the discussion of the clypeus (p. 23). The labrum overlies the bases of the mandibles, and is capable of a limited amount of vertical movement. It is about twice as broad as long, the width being about 0.5 mm. The labrum bears twelve setae which arise from definite tubercles (fig. 5). Four of them, two longer and two shorter, arise from a more heavily chitinized central area. Two pairs of setae arise

from points near the distal edge and in the center of the lobes, and a pair of longer and a pair of shorter setae arise laterad of the aforementioned heavily chitinized central area.

On the inner surface or epipharynx (fig. 6, *ex*) are six sensilla basiconica (*sb*), three on each side, lying in a semicircle, the center one of the three being the larger. There are also several pitlike punctures (*p*) that possibly function as sensilla.

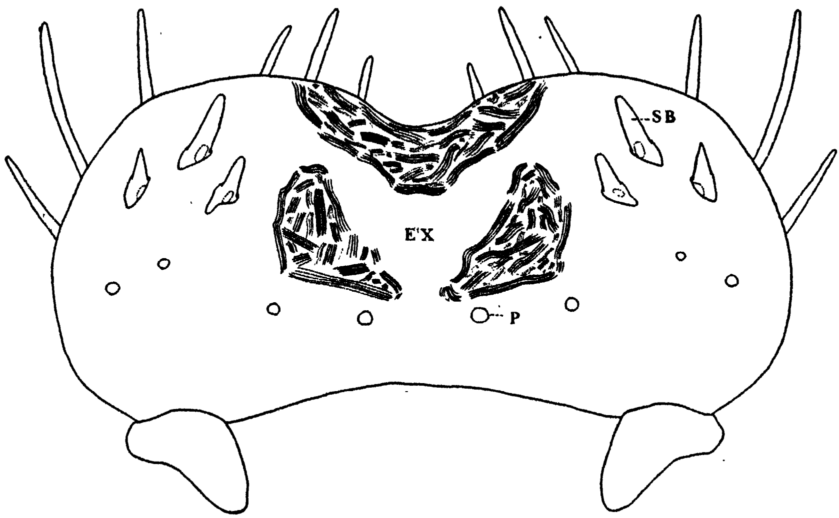

Fig. 6. Ventral aspect of labrum. *ex*, epipharynx; *p*, puncture; *sb*, sensillum basiconica.

Labium.—Occupying the central portion of the ventral surface of the head is the labium (fig. 2, *lb*). The basal parts of the maxillae and labium are united, and the hypopharynx (figs. 3, 7, *hp*) is united to the anterior wall of the labium. The spinneret (*spt*) is located at the tip of the labium. The labium occupies the area limited anteriorly by the bases of the mandibles and posteriorly by the hypostomae (*hs*). Two setae arise from the central portion of the labium. The mentum (*mt*) is posterior to the spinneret.

Labial palpi.—On each side of the spinneret are the labial palpi (fig. 7, *lp*). They are two-segmented, the basal segment being about nine times as long as the distal one. A seta arises from the tip of the basal segment, and the distal segment bears a terminal seta. The total length of the labial palpus is about 0.1 mm. The palpi are surrounded at their bases by a membranous fold, and immediately next to this is a chitinous band which is semicircular with the opening mesad.

Maxillae.—Laterad of the mentum are the maxillae (fig. 2, *mx*). Their chitinous areas are broken up into three plates of varying size, the proximal one is large, irregular, and tapers posteriorly. Laterad of this are two setae. Distad of the large, irregular area are two other chitinous ones with a seta arising from the anterior edge of each. The bases of the maxillary palpus and galea immediately adjoin the anterior chitinous area. A sensillum trichodeum arises from the inner side of the common base of the maxillary palpus and galea.

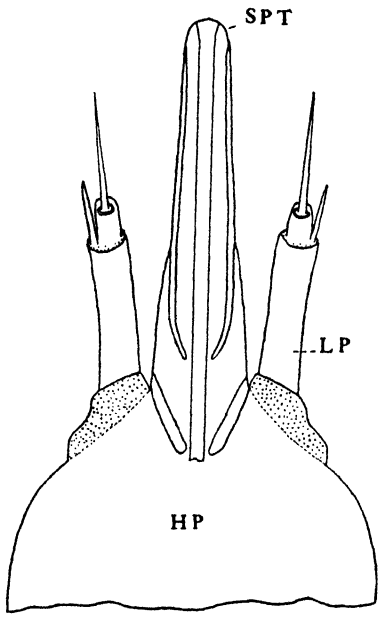

Fig. 7. Dorsal view of tip of hypopharynx with spinneret and labial palpi. *hp*, hypopharynx; *lp*, labial palpus; *spt*, spinneret.

The maxillary palpi (fig. 8, *mxp*) are three-segmented. The basal segment is the larger, being about one and one-half times the length of the second. At the distal end of the second segment are several microscopic projections probably sensory in nature. The third segment is only visible with the high-power objective.

Galeae.—Mesad of the basal segments of the maxillary palpi spring the large basal segments of the galeae (fig. 8, *ga*). The tip of each of these segments bears the two maxillary lobes (*mxl*) which may be the distal segments of the galea and lacinia (Forbes, 1910, p. 98), and dorsally four sensory papillae (*sp*). The central papilla is the largest, those laterad being of the same length as the central papilla but

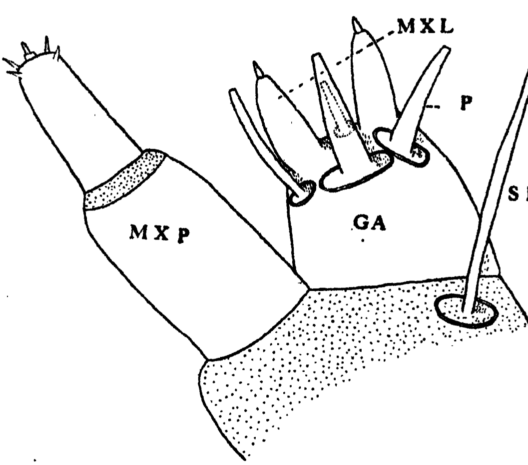

Fig. 8. Dorsal aspect of anterior portion of maxilla showing palpus and galea. *ga*, galea; *mxl*, maxillary lobe; *mxp*, maxillary palpus; *p*, puncture; *sp*, sensory papilla.

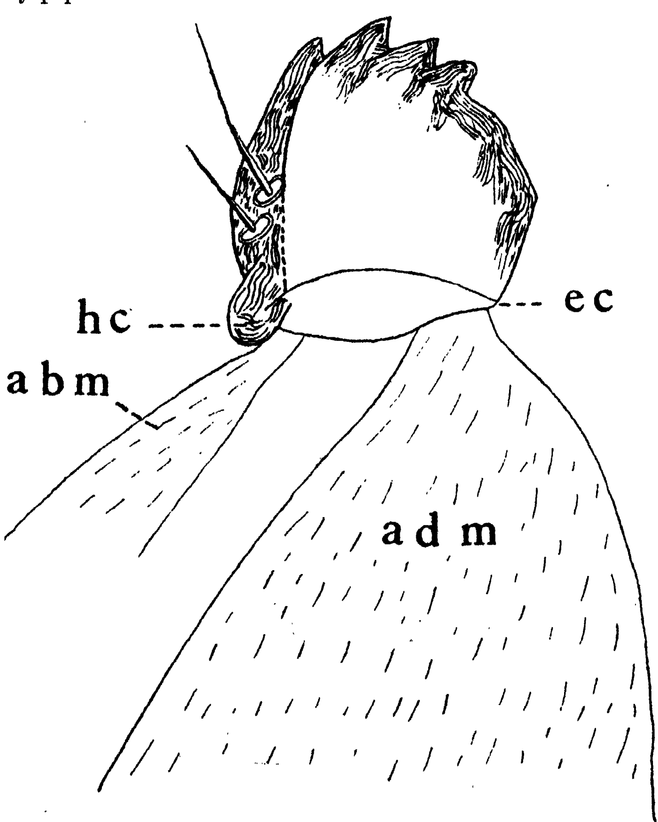

Fig. 9. Dorsal view of mandible. *abm*, abductor muscle; *adm*, adductor muscle; *ec*, epicondyle; *hc*, hypocondyle.

smaller in diameter. The fourth papilla arises between the two maxillary lobes.

Snodgrass (1928, p. 140) states that there are no maxillary palpi on the maxillae of caterpillars in general and terms the structures generally interpreted as such, the "terminal lobes which appear to be the laciniae." He also states (p. 140) that there is no evidence to indicate the presence of a galea, but that the evidence suggests that the lobe is the lacinia alone, complicated in form by the development of a large sensory papillae.

I have labeled these parts maxillary palpi and galeae on the authority of Forbes (1910) and of Crampton (1921).

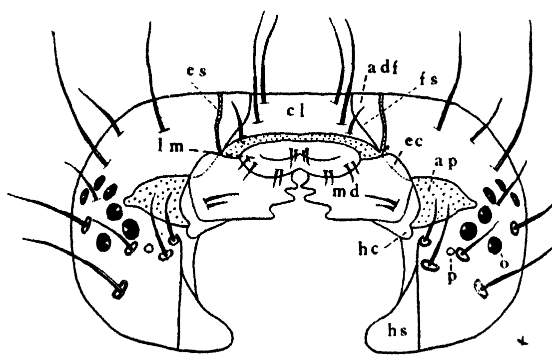

Fig. 10. Frontal aspect of head showing articulation of mandibles. Labrum and antennae removed. *adf*, "adfrons"; *ap*, antennal pit; *cl*, clypeus; *ec*, epicondyle; *es*, epicranial suture; *fs*, fronto-clypeal or epistomal suture; *hc*, hypocondyle; *hs*, hypostoma; *lm*, labrum; *md*, mandible; *o*, ocellus; *p*, puncture.

Mandibles.—The mandibles (figs. 9, 10, 11, *md*) articulate ventrally with the cranial margin of the head by means of the hypocondyles (fig. 10, *hc*), and dorsally with the cranial margin through the epicondyles (*ec*). The mandibles are about 0.4 mm. long, about 0.4 mm. wide, and are five-toothed. They are much darker in the denticulate region. From the dorsal aspect they are convex, and from the ventral aspect concave. Two setae, one long and one short, arise from the dorsal surface of the mandibles.

Mandibulary glands.—Opening at the bases of the mandibles through an orifice (fig. 11, *or*) are the ducts of the mandibulary glands. As to the function of these glands Bordas (1910, p. 192) says, "Les glandes mandibulaires sont des organes à fonction double, à la fois digestive et surtout défensive." No work has been done by the author to verify this statement of Bordas.

The duct follows down the tendon of the adductor muscle (fig. 11, *adm*) of the mandible and becomes enlarged just posterior to the occipital foramen (fig. 13, *mg*). The glands execute several convolutions, and in the region of the third thoracic segment become smaller. The smaller portion executes many more convolutions than does the

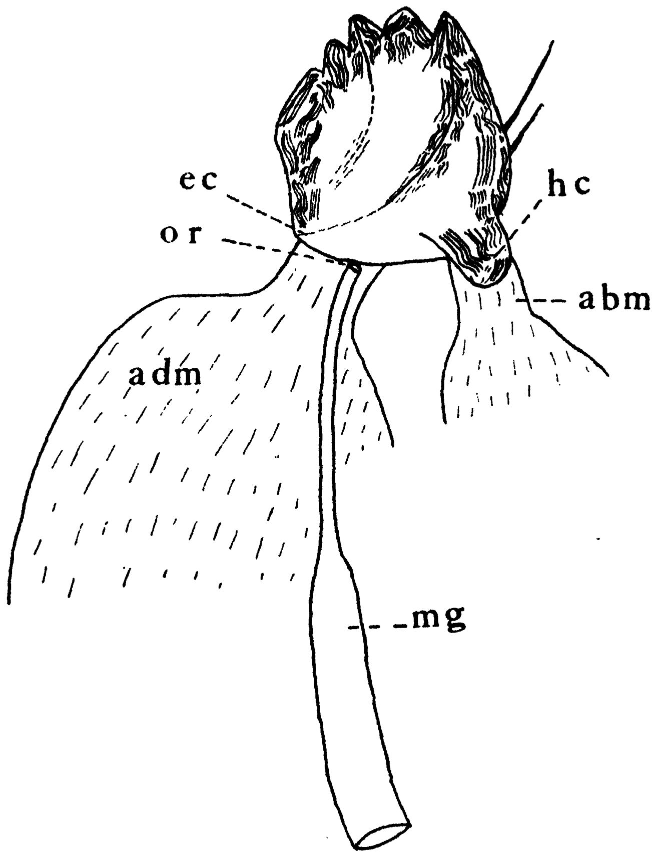

Fig. 11. Ventral aspect of mandible showing opening of mandibulary duct. *abm*, abductor muscle; *adm*, adductor muscle; *ec*, epicondyle; *hc*, hypocondyle; *mg*, mandibulary gland; *or*, orifice.

larger part, and I am unable to verify the following statement of Bordas (1910, p. 184) ". . . . et s'étend jusqu' à l'extrémité postérieure de l'intestin moyen," since hardly any two dissections for this gland gave identical results. In some specimens the glands made a loop in the first abdominal segment and terminated in the thorax. In others they extended far down into the abdomen and may have terminated at the posterior end of the mid-gut as quoted from Bordas.

The larger portion of the glands, lying in the thorax, is irregularly covered with minute nodules (fig. 12), while the posterior portion is

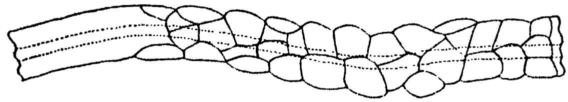

Fig. 12. Nodulated portion of mandibulary gland. Posterior portion to left.

smooth. Further attention will be paid to the change in diameter in the "Discussion," page 35.

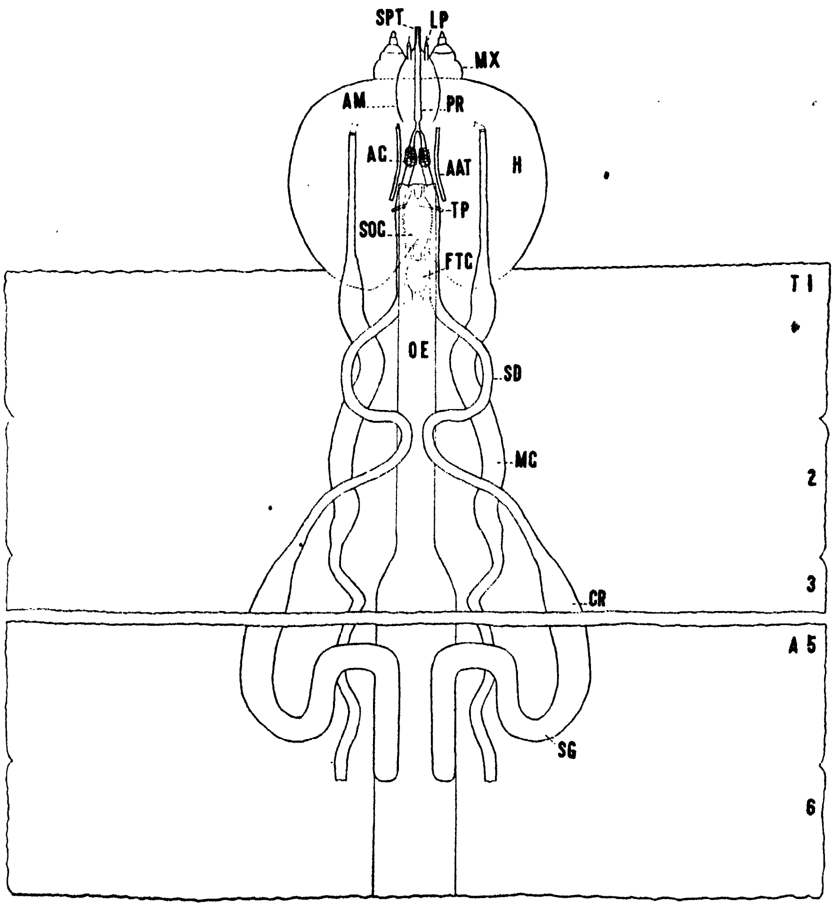

Fig. 13. Diagram of a larva laid open along the dorso-meson showing the silk glands and a portion of the mandibulary glands. For anterior termination of the latter see figure 11.

a, 5–6, segments of abdomen; *aat*, anterior arm of tentorium; *ag*, accessory gland; *am*, mental arm; *cr*, collection reservoir; *ftg*, first thoracic ganglion; *h*, head; *lp*, labial palpus; *mg*, mandibulary gland; *mx*, maxilla; *oe*, oesophagus; *pr*, press; *sd*, silk duct; *sg*, silk gland; *sog*, suboesophageal ganglion; *spt*, spinneret; *t* 1–3, thoracic segments; *tp*, tentorial plate.

Spinneret and silk glands.—Along the ventro-meson anteriorly, lies the spinneret (figs. 2, 7, *spt*). Under natural conditions the spinneret does not extend anteriorly as shown in figure 2, but ventrally. Boiling probably caused the anterior extension. The morphology of the spinneret has not been satisfactorily ascertained, but it appears to be the highly modified ligula (Imms, 1925, p. 407). It may represent the glossae and paraglossae of the generalized labium. The tip of the spinneret is heavily chitinized and is about 0.15 mm. long. It is surrounded at its base ventrally by a membranous area, and has a dark median line extending its entire length (fig. 2, *spt*).

The hypopharynx (fig. 7, *hp*) with the spinneret at its anterior border, is partly surrounded by the heavily chitinized mentum (fig. 2, *mt*) which embraces it ventrally and laterally, but does not extend dorsally except by the mental arms (fig. 13, *am*).

Just back of the spinneret is the press (fig. 13, *pr*), which extends posteriorly about to the lower ends of the mental arms. Posterior to the press is a short constricted area, at the base of which the silk ducts

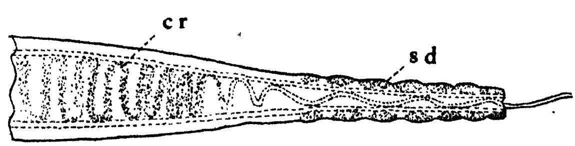

Fig. 14. View of silk-collecting reservoir and duct. *cr*, collection reservoir, *sd*, silk duct.

unite. The silk ducts (fig. 14, *sd*) can readily be distinguished in specimens stained with borax-carmine because of semicircular, crimson areas on the periphery, whereas the silk glands stain uniformly. The ducts are about 0.07 mm. in diameter. In preserved specimens they are of an opaque white color.

Posterior to the conjunction of the ducts are the accessory glands (fig. 13, *ag*), or glands of Lyonnet. These are greatly atrophied and appear as nodulated swellings on the ducts. Bordas (1910, p. 173) says as to the function of the accessory glands, "En résume, nos observations personnelles sur un grand nombre de larves de Lépidoptères nous ont permis de conclure que les glandes annexes ou accessoires, de l'appareil séricigène sécrètent une substance liquide ou légèrement visqueuse servant à unir entre eux les deux fils de soie et, peut-être même, à agir chimiquement sur ces derniers, de façon à permettre leur rapide durcissement." The author has not carried on any experiments to substantiate this statement of Bordas that the

function of the glands is to secrete a fluid which unites the two strands of silk and causes the united strand to harden rapidly.

The silk ducts pass backward on each side of the suboesophageal ganglion (figs. 13, 16, *sog*), pass ventrad of the tentorial plate (figs. 13, 15, *tp*), and begin to enlarge in the region of the second and

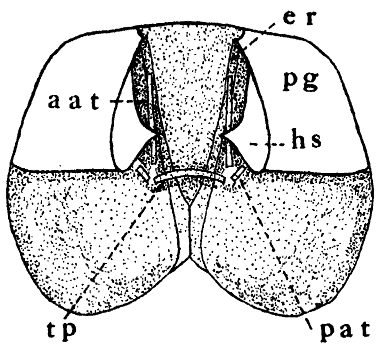

Fig. 15. Ventral view of head capsule with mouthparts and antennae removed, showing tentorium.

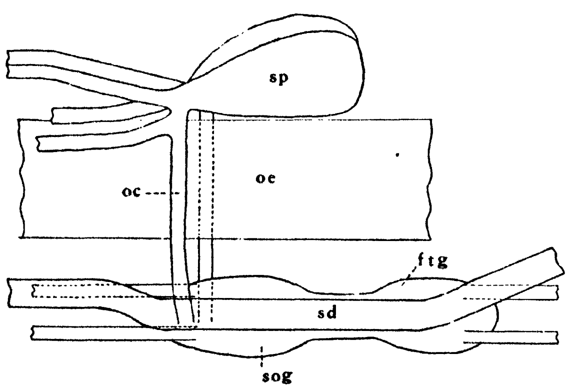

Fig. 16. Diagram of lateral aspect of central nervous system. (Incomplete.) *aat*, anterior arm of tentorium; *er*, epistomal ridge; *ftg*, first thoracic ganglion; *hs*, hypostoma; *oc*, oesophageal connective; *oe*, oesophagus; *pat*, posterior arm of tentorium; *pg*, postgena; *sd*, silk duct; *sog*, suboesophageal ganglion; *sp*, "brain" or supraoesophageal ganglion; *tp*, tentorial plate.

third thoracic segments (fig. 13, *t* 2–3), to form what Bordas (1910) terms the "reservoir collecteur" which is approximately 0.26 mm. in diameter. The reservoirs and glands execute several convolutions over and under the alimentary canal, taper slightly, and terminate in the sixth abdominal segment (*a* 6) as a general rule.

Tentorium.—The tentorium (fig. 15) is composed of five cylindrical, heavily chitinized parts. The posterior arms (*pat*) extend

dorsad and mesad from the meso-posterior border of the hypostomae (*hs*) for a short distance, and bridging the intervening space is the tentorial plate (*tp*) which curves anteriorly. The posterior arms are attached to the hypostomae by a membranous fold (shown clear in the figure). The anterior arms (*aat*) curve dorsally and anteriorly and are attached to the epistomal ridges (*er*) near their anterior ends by a membranous connective similar to that attaching the posterior arms to the hypostomae. The anterior arms, the posterior arms, and the plate are connected by a membranous sheath which surrounds their free ends. The distance between the proximal ends of the anterior arms and the ends of the plate and posterior arms is greater than that between the ends of the plate and the posterior arms. The parts are all of approximately the same diameter, about 0.02 mm.

CENTRAL NERVOUS SYSTEM

(In part)

The following discussion of the central nervous system (fig. 16) and the diagram is incomplete, this section being introduced to show relationship of parts. No attempt has been made to indicate all the nerves arising from the "brain" and suboesophageal ganglion, which with the ventral nerve cord constitute the central nervous system.

DuPorte (1915) worked out the nervous system of *Sphida obliqua* Walker, a noctuid, and for a full discussion of the nervous system of a lepidopterous larva one should refer to his paper.

The "brain" (*sp*) consists of two visible ovoid nerve masses. It lies above the oesophagus (*oe*) between the two anterior arms of the tentorium, with its posterior extremity above the tentorial plate (figs. 13, 15, *tp*) which is ventral to the oesophagus. The nerve masses are joined at one side of their bases and are approximately 0.35 mm. long and about 0.21 mm. wide.

The "brain" is connected anteriorly with the suboesophageal ganglion (*sog*) which is composed of the fused ganglia of the three protocormic segments, by the oesophageal connectives (*oc*), or crura cerebri. The suboesophageal ganglion is about 0.4 mm. long and approximately 0.2 mm. wide or the same width as the "brain" (*sp*). The posterior border of the ganglion gives rise to the two connectives between it and the first thoracic ganglion (*ftg*) and through the latter connects with the balance of the ventral nerve cord. All parts of the nervous system are of an opaque white color.

DISCUSSION

Certain of the lepidopterous larvae such as *Cossus ligniperda* F. have as a part of their mandibulary glands, a well developed collection reservoir (Bordas, 1910, p. 176). Regarding *Carpocapsa pomonella,* Bordas (p. 184) says, "On ne constate, sur le parcours de ces organes aucune dilatation vésiculiforme ni aucune différence de diamètre permettant de reconnaître l'existence d'un réservoir ou d'un conduit excréteur."

My dissections indicate that there is a difference in diameter in these glands. The nodulated portion as described on page 31 is about 0.14 mm. in diameter and the posterior portion is but half that diameter. Whether or not this enlarged region can be construed as a reservoir I cannot say but certainly there is a difference in diameter.

In Bordas (1910, plate X, fig. 3), the labial palpi are shown with two terminal projections or setae, whereas I could find but one terminal seta, and a second arising from the tip of the first segment (fig. 7, *lp*). Since Bordas' figure is semidiagrammatic this point may be of no significance.

There may be some difference in the structure of the mouthparts in different instars of the larvae, and Bordas did not mention which instar his specimens represented. However, on examination of a newly hatched larva, the labial palpi were found as shown in my figures. The suggestion as to differences in structure between different instars of lepidopterous larvae is borne out by the work of Grandi (1922) with *Bombyx mori* wherein he treats each instar separately, presenting a key for determining which instar a larva represents.

Since variations may occur in different instars of the larvae of *Carpocapsa pomonella,* and since so little specific morpohological work has been done on this species, there is excellent opportunity for a great amount of work with an insect which is easily obtainable, comparatively easy to work with, and of great economic interest.

LITERATURE CITED

BORDAS, L.

1910. Les glandes céphaliques des chenilles de lépidoptères. Ann. des Sci. Nat., 3:125–193, pls. 9, 10, 11, 22 figs. in text.

COMSTOCK, J. H.

1924. An introduction to entomology (Comstock Pub. Co., Ithaca, New York), pp. 1–1044, illus.

CRAMPTON, G. C.

1921. The sclerites of the head, and the mouth-parts of certain immature and adult insects. Ann. Entom. Soc. Am., 14:65–103, pls. 2–8.

DUPORTE, E.

1915. On the nervous system of the larva of *Sphida obliqua* Walker. Trans. Roy. Soc. Can., 8:225–253, 8 figs. in text.

FORBES, W. T. M.

1910. A structural study of some caterpillars. Ann. Entom. Soc. Am., 3:94–144, pls. 10–20.

GRANDI, G.

1922. Studi sullo sviluppo postembrionale delle varie razze del *Bombyx mori* L. Portici Lab. di Zool. 16:137–207, 14 figs. in text.

IMMS, A. D.

1925. A general textbook of entomology (Methuen, London), pp. v + 698, illus.

LYONNET, P.

1762. Traite anatomique de la chenille qui ronge le bois du Saule (The Hague), illus.

MONTGOMERY, TH. H.

1900. On nucleolar structures of the hypodermal cells of the larva *Carpocapsa*. Z. Jahrb. Abth. Morph., 13:277–368, pls. 19–25.

PETERSON, A.

1912. Anatomy of the tomato worm larva, *Protoparce carolina*. Ann. Entom. Soc. Am., 5:246–272, pls. 19–21.

SNODGRASS, R. E.

1928. Morphology and evolution of the insect head and its appendages. Smithson. Misc. Coll., 81:1–158. Pt. VII, The head of a caterpillar, pp. 131–153, 5 figs. in text.

LIFE-HISTORY OF BEET LEAFHOPPER, EUTETTIX TENELLUS (BAKER) IN CALIFORNIA

BY

HENRY H. P. SEVERIN

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INTRODUCTION

According to Ball[1, 2] the beet leafhopper, *Eutettix tenellus* (Baker), is a "single-brooded species."

Severin[8, 9] published an account of the life-cycle of the beet leafhopper and reared two broods out-of-doors in the fog-belt district at Berkeley, California, during 1918.

Stahl[13] states that "there was only one brood on sugar beets in southern Idaho, but it seems probable that further investigation would reveal an additional brood, possibly on the wild vegetation." "Experiments conducted at Spreckels, California, demonstrated that there were unquestionably at least two generations annually in that locality. Under conditions more favorable than was usual for this part of the Salinas Valley, a third and even a fourth brood were obtained." In a letter dated May 16, 1921, Stahl informed the writer that two generations were bred out-of-doors and a third and fourth brood in the greenhouse at Spreckels. It is evident thus that two broods occur in the fog-belt district at Berkeley and Spreckels.

Knowlton[5] states that the life-history of the beet leafhopper has not been completely worked out in Utah, but collection data indicate that at least two broods are produced annually in most parts of the state.

According to Haegele[4] "there were two full broods and a partial third brood of the beet leafhopper in southern Idaho in 1926."

The life-cycle of the beet leafhopper was determined at Manteca, situated in the northern part of the San Joaquin Valley, California. A detailed study of the life-history was started with the dark adults (pl. 4, *f–l*) which wintered over in the cultivated areas and the work with the successive broods was conducted during 1919 and 1920. After the first flights of the pale green adults of the spring broods (pl. 4, *a*, *b*, *c*) from the plains and foothills into the cultivated regions during 1919, the number of broods was again ascertained. Various phases of the life-history as determined in cages were checked up in the cultivated districts and on the plains and foothills for a period of eight years.

METHODS OF BREEDINIG

The adults were confined in a cylindrical cage (12 by 8 inches) with top and sides covered with lawn, except a glass plate (10 by 5 inches) through which observations were made (fig. 1). The bottom of each cage was covered with denim fastened with a circular copper wire (fig. 1). The leaves of a sugar beet with the base of the petioles wrapped in cotton projected through two central intersecting incisions

Fig. 1. Cylindrical cages used in life history work, equipped for rapid transfer of beet leafhoppers.

in the denim (fig. 1). The denim rested against two inches of dry sand covering the surface of the soil in a ten-inch pot. The hoppers could be transferred rapidly to another potted sugar beet by blowing a breath of air through the sides and by jarring the cage, causing the insects to change their resting place from the foliage to the cloth; the cage was then lifted so that the leaves pulled through the incisions, leaving the bugs in captivity. This removal of the cage from the potted beet was performed in a dark chamber provided with a glass plate, outside of which was a 50-watt electric lamp covered with a

shade (fig. 2), so that any specimens which perchance remained on the plant, resting between the petioles, were attracted to the light after the cage was removed. In determining the daily emergence of adults of various broods, the insects were removed from the cages with a ten-cubic-centimeter pipette (fig. 3). The glass of each cage faced to the north in the field. Each pot was placed in a saucer (fig. 1) and the

Fig. 2. Dark chamber in which transfers of beet leafhoppers were made to prevent escape of adults. If a leafhopper escaped, it was attracted to the light of an electric lamp enclosed in a reflector outside of the glass plate.

saucers were watered daily during hot weather. To prevent ants from entering the cage, the sides of the saucer were smeared with tanglefoot. All sugar beets used for life-history work were grown under cover in the greenhouse at Berkeley, were transplanted in pots at Manteca, and were fumigated with Nico-Fume tobacco-paper insecticide a week prior to using.

Fig. 3. Method of removing beet leafhoppers from a cage with a ten-cubic-centimeter pipette. By inhaling a breath of air through the rubber tube, the hoppers are drawn into the bulb of the pipette, and by exhaling the breath they are expelled from the pipette. A piece of silk bolting covers the opening between the pipette and rubber tubing. An electric lamp enclosed in a reflector on the top of the cage illuminated and heated the interior of the cage during foggy days.

LIFE-CYCLE

Oviposition.—In the process of oviposition the female cuts an incision in the petiole with her ovipositor (fig. 4), also in the veins or margin of the sugar beet leaves, and a single egg is imbedded in the slit-like egg chamber (pl. 3, *a*). The petiole often becomes bent (figs. 5, 6) at the region where the beet leafhopper deposits its eggs, owing to the fact that the tissue was injured by the ovipositor. The slit-like egg chambers can be readily distinguished from the round mouthpart punctures (fig. 7).

Egg.—The average length of the egg after deposition is 0.654 mm. and the average width 0.0182 mm. Within the tissues of the beet leaves, the outline of the egg becomes irregular in shape (pl. 3, *b*). The egg is translucent when first deposited and during the embryonic development turns pale greenish white or yellow. It is elongated, narrower at one end than at the other, and with a distinction between dorsal and ventral surfaces indicated by a difference in curvature (pl. 3, *b*, *c*). As it nears the hatching period, the anterior pole may protrude from the mouth of the egg chamber and the pink eyes (pl. 3, *c*) of the embryo are visible.

Egg periods.—The egg period was determined twice during each month. Females at the egg-laying stage were confined in a cage enclosing a potted sugar beet for one day and then the cage was replaced by an empty one. Table 1 gives the incubation periods from February to October:

It is evident that temperature plays an important rôle in the duration of the egg period. This is shown more clearly in the diagram (fig. 8) where the curves of the mean temperature and the egg period are plotted at such scales that they are approximately parallel. The larger separation of these curves in October as contrasted with April indicates the greater significance of temperature during the early embryonic development.

Table 1 shows that eggs deposited from November 1 to January 15 failed to hatch. There was a possibility that no eggs were deposited when the females remained on the beet for one day, provided the weather was cold and cloudy. Accordingly, another experiment was conducted in which the leafhoppers were allowed to remain on beets for one-half of a month. This experiment was repeated from November 1 to January 15 and it was certain that oviposition had occurred.

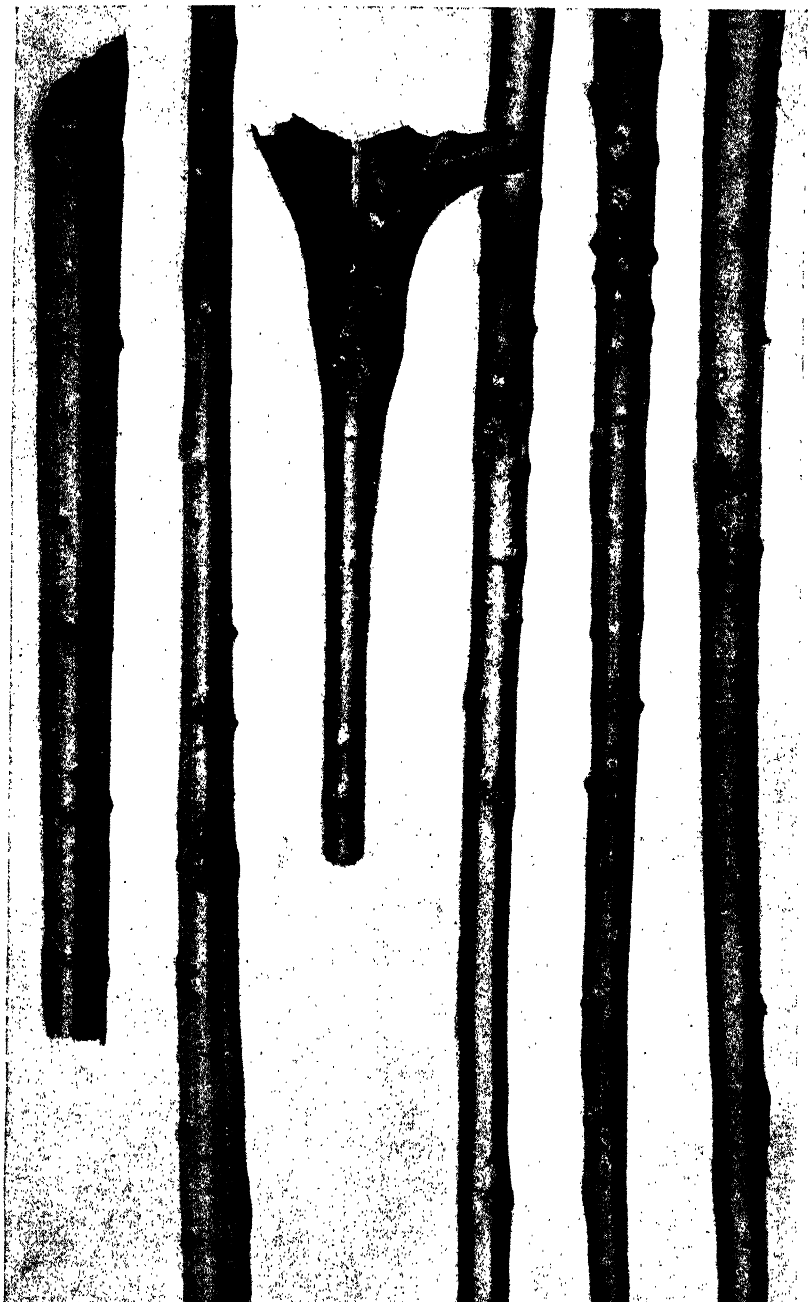


Fig. 4. Petioles of beet showing incisions in which eggs of beet leafhopper were deposited.

Fig. 5. Beet seedlings showing bent leaves in which tissue was injured by ovipositor in depositing eggs.

Fig. 6. Bent leaves enlarged.

A few eggs deposited from December 15 to 31 and January 1 to 15 hatched, but the nymphs died out-of-doors. An examination of the eggs which failed to hatch showed that the epidermis of the petiole covering the eggs had turned brown and a fungus growth was present on some of the eggs but this may have developed secondarily after the eggs were dead. Eggs deposited in November sometimes showed the pink eyes of the embryos but these failed to hatch. During the winter there was a high mortality of the nymphs which hatched from eggs deposited during September and October.

TABLE 1

EGG PERIODS OF BEET LEAFHOPPER

Date of oviposition	Date of hatching	Egg period	Mean temperature
		days	°*F*
Feb. 15	April 7	51	52.9
March 1	April 14	44	55.1
March 17	April 24	38	58.9
April 1	April 30	29	61.6
April 16	May 8	22	64.8
May 2	May 20	18	66.8
May 17	June 2	16	72.2
June 1	June 15	14	69.7
June 16	June 30	14	72.2
July 1	July 12	11	75.6
July 15	July 27	12	75.3
Aug. 1	Aug. 13	12	68.8
Aug. 16	Aug. 28	12	78.3
Sept. 1	Sept. 18	17	67.1
Sept. 15	Sept. 26	11	73.3
Oct. 1	Oct. 28	27	60.0
Oct. 15	Nov. 12	28	54.3
Nov. 1	Failed to hatch		
Nov. 15	Failed to hatch		
Dec. 1	Failed to hatch		
Dec. 15	Failed to hatch		
Jan. 1	Failed to hatch		
Jan. 15	Failed to hatch		

A comparison was made of the dates of the first hatching of eggs deposited by dark adults wintering in the cultivated areas with those on the plains and foothills. Eggs deposited in the leaves of a beet on February 15, 1919, by dark females wintering in the cultivated areas, hatched on April 7 (table 1) in a cage. December-planted beets with eggs deposited in the petioles of the first pair of true leaves under natural conditions (figs. 5, 6) were transplanted in pots on March 20,

the first nymph hatched on April 14, and the first adult emerged on May 13. Eggs deposited in beet foliage from January 17 to February 3 by dark females which wintered on the plains and foothills hatched between March 3 and 14. Eggs deposited by pale yellow females (pl. 2, *d, e*) of the second and third broods which wintered over in cages in the cultivated area hatched between March 16 and 31, 1920, and the nymphs were reared to adult stage.

Fig. 7. Mouth-part punctures of beet leafhopper in blades of sugar beets.

Hatching.—During the process of hatching, the nymph, enclosed in the chorion and amniotic and vitelline membranes, pushes out of the slit-like aperture of the egg chamber (pl. 3, *d*). The nymph, after extrication from the egg shell and embryonic membranes (pl. 3, *e, f*), may remain suspended with the tip of the abdomen in the embryonic envelopes with legs sprawled apart. After the chitin hardens, the nymph crawls away (pl. 3, *g*) and usually settles on the lower surface of the leaf to take its first meal.

Stadia.—The interval or periods between the molts (stages or stadia) and the total duration of these periods or the post-embryonic development in the beet leafhopper is given in table 2. In this table the specimens are arranged in two groups, the grouping made according to whether the insects molted five or six times.

It is seen from table 2, that the period between molts varied from 4 to 12 days in beet leafhoppers which cast their skins five times and from 2 to 8 days in specimens which molted six times. The most striking difference occurs in stadium V, requiring averages of 10 days and 2.6 days respectively. The average interval between the last two molts (stadia V and VI) of nymphs which passed through six molts required 8.6 days compared with 10 days for hoppers which passed through five molts (stadium V).

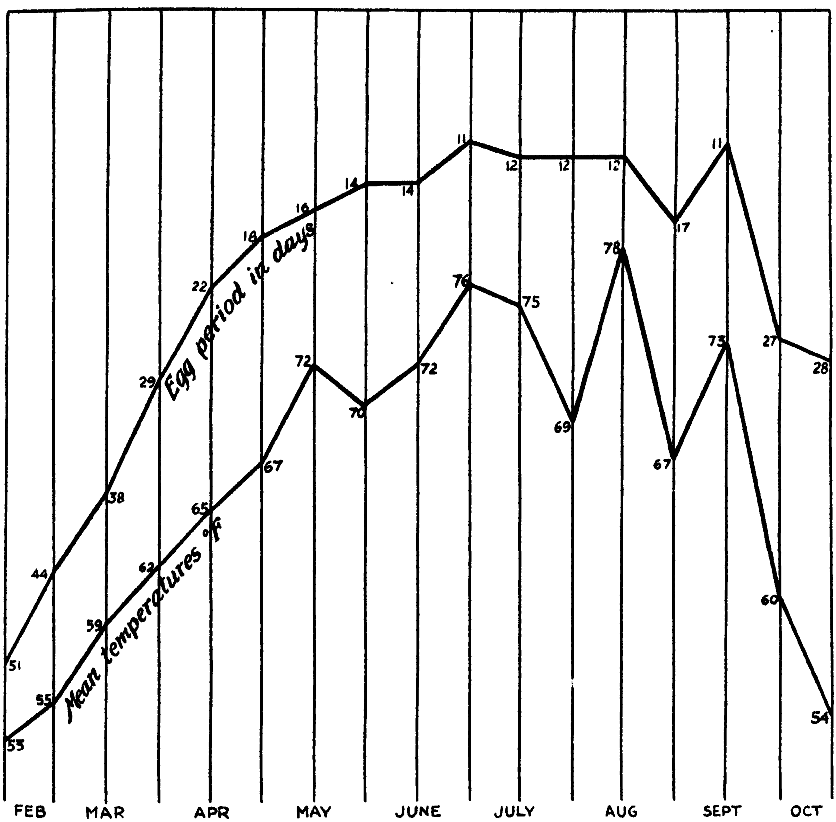


Fig. 8. Diagram showing curves of the mean temperature and egg period plotted at such scales that they are approximately parallel. The larger separation of these curves in October as contrasted with April indicates the greater significance of temperature during the early embryonic development.

Molting.—There are certain indications which appear a day or two before the nymph molts. The body becomes distended, the membranous connections between the head and thorax and abdominal segments become greatly stretched (pl. 1, *g*) ; the abdomen shows a rounding out, a fulness and plumpness.

TABLE 2

DURATION (IN DAYS) OF STADIA OF BEET LEAFHOPPER REARED IN SEPTEMBER

Date of hatching	Sept. 11	Sept. 5	Sept. 5	Sept. 11	Sept. 11	Average	Sept. 5	Sept. 5	Sept. 11	Sept. 5	Sept. 5	Average
Number of molts	5	5	5	5	5	....	6	6	6	6	6	....
Stadium I	5	9	8	5	5	6.4	6	6	5	8	8	6.6
Stadium II	4	5	6	4	6	5.0	4	4	4	5	5	4.4
Stadium III	4	4	5	4	4	4.2	5	5	4	5	5	4.8
Stadium IV	5	5	7	5	5	5.4	4	4	7	6	6	5.4
Stadium V	9	9	10	10	12	10.0	2	2	5	2	2	2.6
Stadium VI	....	....	....	....	....	....	5	5	4	8	8	6.0
Total post-embryonic development	27	32	36	28	32	31.0	26	26	29	34	34	29.8
Date of last molt	Oct. 8	Oct. 7	Oct. 11	Oct. 9	Oct. 13		Oct. 1	Oct. 1	Oct. 10	Oct. 9	Oct. 9	
Sex	♂	♂	♂	♀	♀		♂	♂	♂	♂	♀	
Temperatures	°F	°F	°F	°F	°F		°F	°F	°F	°F	°F	
Mean maximum	96	95	95.0	96	95		96.0	96.0	96	95	95	
Mean minimum	54	55	54.0	54	53		53.0	53.0	56	55	55	
Mean	75	75	74.5	75	74		74.5	74.5	76	75	75	

TABLE 3

AVERAGE MEASUREMENT IN MILLIMETERS OF BEET LEAFHOPPER PREVIOUS TO AND AFTER EACH MOLT

	Length, head to end of wings	Length, head and body		Diameter, head	
		After molt	Previous to molt	After molt	Previous to molt
I Instar	....	0.805*	1.130	.305*	.305
II Instar	....	1.160	1.520	.400	.400
III Instar	....	1.415	1.885	.505	.510
IV Instar	....	1.850	2.380	.635	.615
V Instar	....	2.415	3.200	.760	.825
VI Instar	....	2.750	3.200	.800	.750
Male after fifth molt	3.63	2.81	....	.800	....
Female after fifth molt	3.65	3.15	....	.900	....
Male after sixth molt	3.40	2.90	....	.812	....
Female after sixth molt	3.70	3.10	....	.900	....

* Length of head and body and diameter of head after hatching.

After molting the nymph often remains suspended by the tip of the abdomen in the molted skin (pl. 4, *c*) with legs sprawled apart. The adult is white in color after the last molt and the wings expand rapidly (pl. 4, *a*). The insect holds the elytra away from the lower wings until the chitin hardens (pl. 4, *b*).

Measurements of instars.—The average measurements of various parts of the body of ten specimens one day previous to and one day after each molt are given in table 3. The diameter of the head was measured across the compound eyes.

It is evident from table 3 that the instars can be determined more readily by the measurements of the head across the compound eyes, except after the fourth and fifth molts. A comparison of the average measurements of the male and female beet leafhoppers which completed five and six molts, shows that the males are somewhat smaller than the females.

Color of nymphal instars.—The recently hatched nymph is white with reddish brown compound eyes (pl. 1, *a*). A few hours after hatching, the body of the nymph is pale yellow marked with light brown areas on the thorax and abdomen. The compound eyes are greenish yellow. Previous to the first molt the body is yellowish white with gray areas on the thorax and abdomen (pl. 1, *a*).

Shortly after each molt the body of the nymph is usually white (pl. 1, *h*), sometimes pale lemon yellow after the fourth molt (pl. 1, *i*). The color of the body changes to yellow with dark brown or black blotches (pl. 1, *b*) which have a purple iridescence after the third, fourth, and fifth molts. After the first and second molts the brown areas may be mottled with pink (pl. 1, *j*). The compound eyes are usually greenish yellow or yellow, sometimes with a red crescent (pl. 1, *e*, *f*) around them after the fourth and fifth molts.

Color of adults.—In the hot interior regions of California, there is considerable variation in the color of the dorsal part of the head and thorax and this contrast in color will be described for the spring, summer, and overwintering adults.

Spring form.—The adults which acquire the winged stage in March and early April on the plains and foothills possess a pale green vertex and pronotum, also hyaline elytra with dark areas (pl. 2, *a*, *b*). Later in the spring, pale green adults develop on the plains and foothills without markings on the wing covers (pl. 2, *c*). The eyes of the living specimens are pale green.

Summer form.—The prevailing color of the vertex and pronotum of the adults emerging in the summer is pale yellow (pl. 2, *d*), sometimes greenish yellow. These structures in other specimens may be lemon yellow (pl. 2, *e*) especially during the autumn.

Overwintering form.—The adults wintering on the plains and foothills vary considerably in color, the prevailing color of the vertex and pronotum being pale yellow, often with dark brown areas (pl. 2, *f, i, j, k, l*). The wings are subhyaline marked with brown or black blotches between the veins. In some specimens the dorsal part of the head and prothorax was pale yellow with pink areas and blue elytra with brown spots (pl. 2, *g*). A rust-colored adult (pl. 2, *h*) was taken on the foothills on rare occasions. The compound eyes of the dark overwintering adults were usually brown.

Characteristics of species.—A number of different species of leafhoppers occur in beet fields and are often confused with *Eutettix tenellus.* The female beet leafhopper can readily be determined by the semicircular emargination (pl. 4, *g*) of the last ventral segment of the abdomen. The plates (pl. 4, *d*) at the end of the abdomen distinguish the male from other species. The characteristics of the genitalia of either sex should be used to identify the species rather than the variable color pattern of the adults.

SPRING BROOD

On plains and foothills.—In two papers[8, 9] on the life-history of the beet leafhopper, the statement was made that no breeding experiments were conducted on the plains and foothills to determine the number of broods, and it was assumed that the pale green adults which invade the cultivated areas represent the spring brood. There was no doubt that one generation developed on red stem filaree (*Erodium cicutarium;* fig. 9) growing on the plains and foothills after the appearance of large numbers of nymphs, and mating of enormous numbers of adults occurred previous to the flights into the cultivated areas. It was assumed, however, that a partial second brood may complete its life-history providing the pasture vegetation does not dry up too rapidly. Evidence accumulated in later years indicates that a partial second brood develops on the plains and foothills of the San Joaquin Valley whenever late spring rains occur and the pasture

vegetation remains green. During the 1925 outbreak of the beet leafhopper a partial second brood developed on the foothills of the Salinas Valley.[12]

The spring brood adults with dark areas on the wing covers have often been mistaken for the dark overwintering specimens on the plains and foothills. The pronotum of some of the dark overwintering leafhoppers taken in March on the plains and foothills of the San

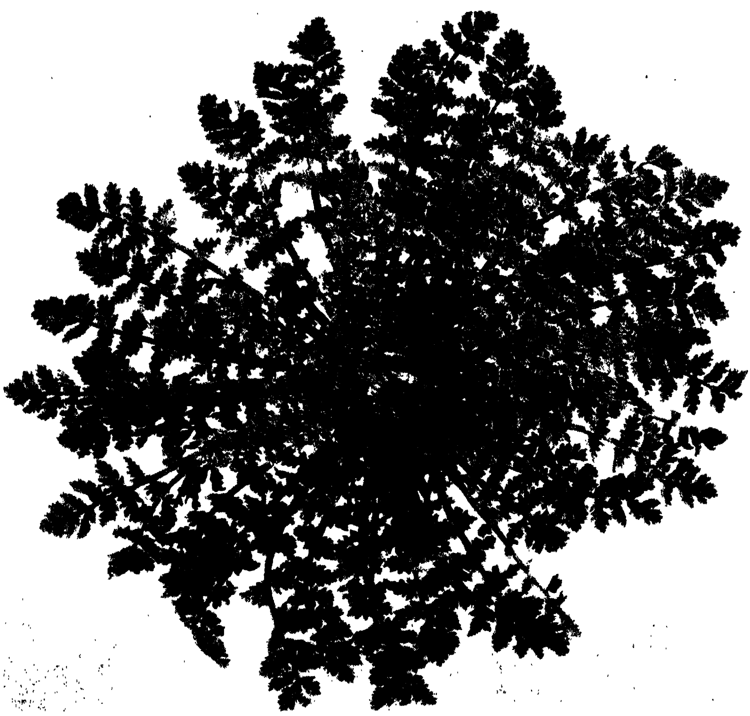


Fig. 9. Rosette form of red stem filaree (*Erodium cicutarium*) which is the most important food and breeding plant on the plains and foothills, of the beet leafhopper.

Joaquin Valley changed color from yellow to yellowish green or pale green. This change in color was also observed in May in a natural breeding area of the beet leafhopper in the Sierra Nevada Mountains[11]. During the twelve years in each of which the dark overwintering insects were kept in cages in the greenhouse there was only one year in which this change in color occurred.

It is possible to distinguish the pale green spring brood adults with dark areas on the wing covers from the dark overwintering specimens

which have changed color on the pronotum from yellow to yellowish green or pale green. The elytra of some of the overwintering females taken in March and May were often worn and the dark markings faded, indicating the approach of old age. Dissections of the pale green adults with dark areas on the elytra, shortly after these acquire the winged stage, show that the ovaries are immature and contain no full-grown eggs. On March 24, 1921, not a single spring brood adult with dark areas on the wing covers, collected in Little Panoche Pass, had mature eggs in the ovaries whereas 100 per cent of the dark overwintering females were at the egg-laying stage. On April 8, 1921, 5 per cent of the pale green females without markings on the wing covers captured in Little Panoche Pass had fully developed eggs in the ovaries.

During March and April pale green spring brood males with dark areas on the wing covers were commonly taken in Little Panoche Pass. The dark overwintering males follow the females to the plains and foothills, mate in the autumn, and die during the winter. It is evident that the pale green males with dark areas on the elytra belong to the first brood.

Proportion of sexes.—The females of the spring brood greatly outnumbered the males after a large flight had occurred on April 14, 1919, into the cultivated areas of the middle San Joaquin Valley. Table 4 indicates the proportion of sexes taken on different host plants.

TABLE 4

PROPORTION OF SEXES AFTER FLIGHTS OF SPRING BROOD ADULTS INTO CULTIVATED AREAS

Date of collection	Plant	Locality	Number of males	Number of females
April 15	Fog weed (*Atriplex argentea expansa*)	South Dos Palos	50	291
April 15	Russian thistle (*Salsola kali tenuifolia*)	Oro Loma	29	167
April 16	Sugar beets (*Beta vulgaris*)	Chowchilla	0	179
April 17	Sugar beets	Hatch	0	50
April 21	Russian thistle	Oro Loma	13	87
April 23	Sugar beets	Hatch Station	2	111
April 25	Sugar beets	Hatch Station	2	252
April 28	Heartscale (*A. cordulata*)	Oro Loma	7	93
			103	1230
			8%	92%

During the spring most of the pale green males of the spring broods remain on the plains and foothills, and are common on peren-

nials after the pasture vegetation becomes dry, but are rarely taken during the summer, and probably die. Table 5 shows a gradual increase in the percentage of males in a mountain pass during the spring dispersal.

TABLE 5

PROPORTION OF SEXES OF SPRING BROOD ADULTS IN LITTLE PANOCHE PASS DURING SPRING DISPERSAL

Date of collection	Plant	Locality	Males	Females
1920			No. %	No. %
April 19	Red stem filaree (*Erodium cicutarium*)	Little Panoche Pass	160–55	129–45
April 24	*E. cicutarium*	Little Panoche Pass	715–70	301–30
April 29	*E. cicutarium*	Little Panoche Pass	166–73	62–27
May 11	*E. cicutarium*	Little Panoche Pass	366–84	67–15
May 11	Alkali heath (*Frankenia grandifolia*)	Little Panoche Pass	200–78	56–22
June 1	Alkali heath and *Hemizonia virgata*	Little Panoche Pass	201–89	25–11
			1808	640

Egg-laying stage.—The pale green females of the spring brood are mostly at the egg-laying stage after the dispersal into the cultivated districts has occurred. Fifty females were captured in a beet field near Chowchilla on April 16, after the flight on April 14, and 92 per cent had mature eggs in the ovaries.

Fifty females collected on the plains and foothills on April 28 were dissected and 20 per cent had fully developed eggs in the ovaries. In all probability, most of these females became gravid after the enormous flight occurred on April 14.

Egg and nymphal periods in cultivated areas.—The duration of the egg and nymphal periods of the first brood was also determined. For this purpose 2 dark males and 122 dark females which wintered in the cultivated areas were collected on beet seedlings with one pair of leaves on February 12, 1919, at Hatch Station. All these leafhoppers were confined in a cage enclosing the foliage of a sugar beet in order to be certain that oviposition occurred during the low temperatures in February. During March the number was reduced to 50 females. The insects were transferred to a new beet each week and also bimonthly from March to June, until the last specimen died on September 3. Table 6 gives the details.

TABLE 6

EGG AND NYMPHAL PERIODS OF FIRST-BROOD BEET LEAFHOPPERS IN CULTIVATED AREAS

Dates of oviposition	Date of first hatching	Minimum egg periods	Date first adult issued	Date last adult issued	Minimum nymphal period	Egg and nymphal periods	Mean temperature
		days			*days*	*days*	°F
Feb. 15–23	April 7	51	May 7	May 10	30	76–81	57.0
Feb. 24–28	April 20	55	May 19	June 7	29	84–99	61.4
March 1–2	April 14	44	May 13	May 24	29	73–83	60.1
March 3–9	April 20	48	May 18	June 1	28	76–84	61.5
March 10–16	April 20	41	May 19	June 4	29	70–79	63.0
March 17	April 24	38	May 21	June 2	27	65–77	63.8
March 18–24	April 24	37	May 21	June 4	27	64–72	64.3
March 25–31	April 29	35	May 25	June 6	26	61–67	65.4
April 1	April 30	29	May 26	June 4	26	55–64	66.1
April 2–8	April 30	28	May 26	June 11	26	54–64	66.3
April 9–15	May 1	22	May 28	June 20	27	49–66	67.0
April 16	May 8	22	June 3	June 14	26	48–59	67.8
April 17–23	May 10	23	June 6	June 22	27	50–60	67.9
April 24–May 1	May 12	18	June 8	June 25	27	45–55	68.8
May 2	May 20	18	June 13	June 23	24	42–52	69.1
May 3–9	May 25	22	June 21	July 3	27	49–55	69.3
May 10–16	May 30	20	June 24	July 10	25	45–55	70.6
May 17	June 2	16	June 25	July 6	23	39–50	70.5
May 18–24	June 2	15	June 25	July 18	23	38–55	72.1
May 25–31	June 6	12	June 29	July 26	23	35–56	72.8
June 1	June 15	14	July 12	July 23	27	41–52	72.6
June 2–8	June 16	14	July 10	July 31	24	38–53	72.1
June 9–15	June 25	16	July 18	July 30	23	39–45	72.0
June 16	June 30	14	July 25	Aug. 5	25	39–50	72.6
June 17–22	July 1	14	July 24	Aug. 15	23	37–54	72.4
June 23–29	July 7	14	July 31	Aug. 17	24	38–49	72.6
June 30–July 6	July 12	12	Aug. 6	Aug. 20	25	37–45	73.0
July 7–13	July 18	11	Aug. 14	Aug. 30	27	38–48	74.6
July 14–20	July 27	13	Aug. 26	Sept. 7	30	43–49	73.0
July 21–27	Aug. 5	15	Sept. 1	Sept. 18	27	42–53	71.3
July 28–Aug. 3	Aug. 13	16	Sept. 6	Sept. 20	24	40–48	71.4
Aug. 4–10	Aug. 19	15	Sept. 22	Sept. 28	34	49–49	71.7
Aug. 11–17	Aug. 28	17	Sept. 25	Oct. 7	28	45–51	70.5
Aug. 18–24	Aug. 31	13	Oct. 7	Oct. 14	37	50–51	69.5
Aug. 25–31	Sept. 15	21	Oct. 17	Oct. 23	32	53–53	67.1
Sept. 1–3	Sept. 27	26	*	*	....	....	....

* Sept. 30, nymphs killed by 0.47 inch of rain.

If we are justified in assuming that eggs deposited on the first day of each week were first to hatch as indicated in table 7, then the minimum egg stages of the first brood varied from 11 to 55 days. If the nymphs which hatched from these eggs were first to reach the adult stage, then the minimum nymphal periods required from 23 to 37 days.

The duration of combined egg and nymphal periods of the first brood varied from 35 to 99 days.

Daily emergence of adults.—A daily record was obtained of the number of male and female adults of the first brood reared from eggs deposited by the dark females captured on beet seedlings. In table 7 the letter "d" with a digit in parenthesis, shows the number of dark overwintering adults that were bred; all other figures indicate the number of pale green or yellow specimens which issued.

TABLE 7

DAILY EMERGENCE OF FIRST BROOD MALE AND FEMALE BEET LEAFHOPPERS IN CULTIVATED AREAS

Date	May		June		July		August		September		October	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1	......	......	43	30	58	48	16	8	0	4	0	0
2	......	......	43	37	46	88	11	14	0	3	0	0
3	......	......	36	42	50	50	11	9	4	3	0	0
4	......	......	43	29	47	43	8	10	0	1(1*d*)	1(1*d*)	1(1*d*)
5	......	......	33	43	28	36	7	9	2	0	0	0
6	......	......	25	21	22	40	10	17	3	2	1	0
7	0	1	20	17	38	21	9	9	3(1*d*)	1	1	2(2*d*)
8	1	1	28	35	35	35	4	11	1	0	0	0
9	1	1	30	29	21	24	10	4	0	0	0	0
10	1	1	22	24	15	38	5	7	0	0	0	0
11	0	0	31	20	32	19	7	7	0	0	0	0
12	0	0	23	16	31	24	7	11	1(1*d*)	2(2*d*)	0	1(1*d*)
13	1	0	22	26	39	20	3	5	2	1(1*d*)	0	0
14	0	0	17	24	39	23	3	8	2(1*d*)	0	0	1(1*d*)
15	3	0	20	29	29	28	5	5	3(1*d*)	0	0	0
16	2	3	28	31	25	41	5	8	2(1*d*)	0	0	0
17	1	1	15	13	38	43	5	4	0	0	0	1(1*d*)
18	5	1	23	18	28	30	3	4	0	1(1*d*)	1(1*d*)	0
19	3	5	10	28	17	16	4	8(2*d*)	0	1(1*d*)	0	0
20	4	2	2	15	14	18	4	4	1	0	0	0
21	5	2	7	12	22	19	5	1	0	0	1(1*d*)	1(1*d*)
22	9	9	19	12	7	12	4	6	2	0	1(1*d*)	0
23	9	13	43	27	21	13	6	4	1	0	0	1(1*d*)
24	17	9	56	46	11	14	2	6	0	1(1*d*)	....	....
25	16	14	75	47	11	5	1	1	1	1(1*d*)	....	....
26	39	35	67	58	15	16	1	2	2	1(1*d*)	....	....
27	27	28	72	64	4	7	1	1	1	0	....	....
28	25	23	78	60	9	7	1	5	1	0	....	....
29	30	47	75	63	6	16	0	1	0	0	....	....
30	31	23	52	70	17	9	3	4	2	0	....	....
31	37	26	......	......	9	9	3	2	....	....	....	....
	267	245	1058	986	784	812	164	195(2*d*)	34(5*d*)	22(9*d*)	6(4*d*)	8(8*d*)
	*68.8°		*69.9°		*74.5°		*73.8°		*68.4°		*59.1°	

* Mean temperature °F. (*d*) = Dark overwintering adults.

The maximum period of emergence of the first-brood adults occurred during the months of June and July, and the largest number of specimens issued between June 24 and July 3. The first adult issued on May 7 and the last on October 23, extending over a period of about 5⅔ months in which the first brood acquired the winged stage. The period between the deposition of the first egg, on February 15, and the emergence of the last adult, on October 23, required about 8⅓ months. The last eggs hatched on September 27, but the nymphs were killed by 0.47 inch of rain on September 30. Occasionally small nymphs remained in the cages after most of the bugs had acquired the winged stage and these usually died, or if they passed through the last molt, the wings of the adults did not expand properly (fig. 10).

Fig. 10. Beet leafhopper with malformed wings.

A total of 2313 males and 2268 females were bred, or 45 more males than females. During the months of May and June more males than females issued, but in July and August the reverse was evident. The following percentage of dark overwintering adults issued monthly: August 0.5 per cent, September 25 per cent, and October 86 per cent.

Preoviposition period.—An attempt was made to determine the number of days required before fully developed eggs appeared in the ovaries after the first-brood females acquired the winged stage. After the adults had been kept in cages enclosing sugar beets for a period varying from 3 to 17 days, the females were dissected, and they were judged to be at the egg-laying stage when ripe eggs were found in the ovaries. The fact that eggs were often found in the oviducts and common oviduct indicated that these were ready to be deposited. Table 8 shows the results.

TABLE 8

PERIOD AFTER EMERGENCE OF FIRST BROOD BEET LEAFHOPPERS BEFORE EGGS ARE DEVELOPED

Date of emergence	Date of dissection	Days adults were kept in cages	Number of adults with ripe eggs	Number of adults without ripe eggs	Mean temperature
					°F
July 9	July 12	3	1	14	80.3
July 18	July 21	3	0	27	77.1
May 22	May 26	4	0	2	70.3
May 29	June 2	4	1	40	73.3
May 31	June 1	4	2	38	74.7
July 8	July 12	4	2	22	80.9
May 28	June 2	5	5	14	74.1
June 26	July 1	5	5	49	69.1
July 16	July 21	5	5	27	75.7
July 17	July 22	5	10	10	77.0
May 22	May 28	6	0	3	73.4
May 24	May 30	6	1	1	73.5
May 27	June 2	6	6	13	75.5
June 4	June 10	6	2	41	70.9
July 15	July 21	6	6	14	77.5
May 25	June 1	7	3	1	74.5
June 25	July 2	7	14	19	69.9
July 7	July 14	7	4	2	79.2
July 14	July 21	7	7	11	77.3
June 1	June 9	8	3	16	73.7
July 4	July 12	8	24	12	77.4
May 21	May 30	9	1	0	72.2
July 1	July 10	9	7	30	74.7
July 3	July 12	9	25	13	77.0
May 20	May 30	10	1	0	72.1
June 21	July 1	10	7	10	70.6
July 12	July 22	10	8	0	77.1
July 13	July 23	10	5	6	76.5
June 29	July 14	15	6	43	74.4
June 14	July 1	17	12	16	69.4
July 6	July 23	17	16	10	77.6

According to table 8, one specimen, of 42 females dissected, required only three days before apparently mature eggs were present in the ovaries, but no ripe eggs were found in the oviducts and common oviduct. From the data at hand, no conclusions can be drawn as to the maximum and average preoviposition periods.

Egg-laying capacity.—To determine the number of eggs which a single female of the first-brood deposits out-of-doors during her life, a male and a female were confined in a cage enclosing a sugar beet. The

male acquired the winged stage on May 8 and the female on May 9. The eggs were allowed to hatch and the total number of nymphs removed from the cage would equal the egg-laying capacity, providing all of the eggs hatched. The nymphs were removed twice during each month and the records follow:

June 15	91 nymphs	
June 30	114 nymphs	
July 16	86 nymphs	
July 30	28 nymphs	Male died.
Aug. 16	9 nymphs	
Nov. 20	No nymphs	Female died.
	328 nymphs	

The egg-laying capacity of four females was also determined in the greenhouse, using sugar beets and black mustard (*Brassica nigra*) as host plants. The number of nymphs which hatched from eggs deposited by each female in these host plants was as follows: sugar beets 258, 392; black mustard 291, 383, or an average of 341.

Parthenogenesis.—Parthenogenesis is common among the Hemiptera, but the eggs of the beet leafhopper do not hatch without fertilization. Fifty-one females which passed through the last molt on June 2 were dissected ten days later and six specimens had apparently mature eggs in the ovaries. Thirty-six females which acquired the winged stage on June 3 were confined in a cage until February 12, when the last specimen died, but all eggs which were deposited in the leaves of a sugar beet failed to hatch.

Longevity.—The longevity of 60 males and 40 females of the spring brood collected on April 28, 1919, on the plains near the foothills of the Coast Range in the middle San Joaquin Valley was determined in a cage kept out-of-doors at Manteca. The leafhoppers were transferred to cages enclosing sugar beets on the dates indicated in table 9, so that no nymphs had an opportunity to acquire the adult stage. Some of the insects were killed by parasites.

Since the date that the beef leafhoppers acquired the winged stage was not known with the 100 specimens collected on the plains, the length of adult life was again determined with bugs that were bred and had just acquired the wings. The rate of mortality is shown in table 9.

It is evident from table 9 that the longest life of the males was about four months and a few females lived through the winter, or a period of about nine months.

TABLE 9

LONGEVITY OF FIRST BROOD ADULT BEET LEAFHOPPERS

Collected on plains			Progeny from dark females wintering in cultivated areas					
Date	Adults alive		Date	Adults alive		Date	Adults alive	
	♂	♀		♂	♀		♂	♀
April 28	60	40	June 28	78	60	July 9	50	26
June 7	9	15	July 23	72	58	Aug. 1	29	21
June 30	6	13	Aug. 4	68	58	Sept. 15	5	10
July 21	1	9	Aug. 17	65	55	Oct. 4	3	8
Aug. 5	0	7	Sept. 7	8	27	Nov. 1	2	6
Aug. 19	...	3	Oct. 4	2	12	Jan. 3	0	3
Sept. 7	...	1	Nov. 1	2	10	Jan. 17	...	2
Oct. 2	...	0	Jan. 3	0	5	Feb. 12	...	2
			Jan. 17	...	4	March 3	...	2
			Feb. 12	...	1	March 15	...	2
			March 3	...	1	March 31	...	2
			March 15	...	1	April 16	...	1
			March 31	...	0	May 1	...	0

Under natural conditions it is impossible to determine the longevity of the spring-brood adults, owing to the resemblance in color of the summer-brood forms, which show color variation from yellow to greenish yellow. Pale green adults of the spring broods do not live through the winter under field conditions.

SECOND BROOD

Bred through one brood from dark females wintering in cultivated areas.—As soon as a few pale green adults of the first brood were bred from eggs deposited by the dark females wintering in the cultivated areas, they were confined in a cage enclosing a sugar beet, for the purpose of determining the emergence of the second-brood adults. Three males and four females issued on May 7 to 10, as indicated in table 7, and these were transferred to a new beet about once a month until the last specimen died between December 15 and January 3. Heavy winds blow during the spring and cages are liable to be upset; therefore a duplicate experiment was performed with fourteen males and eleven females bred from May 13 to 24. In the second experiment the last female died between January 3 and 15. In the first experiment

a female of the second brood acquired the winged stage on July 5, and in the second cage a male was bred on June 30; hence the data on the emergence in the two experiments are combined in table 10.

TABLE 10

EMERGENCE OF SECOND-BROOD MALE AND FEMALE BEET LEAFHOPPERS BRED THROUGH ONE GENERATION FROM DARK FEMALES WINTERING IN CULTIVATED AREAS

Dates	June	July		August		September		October		November		December
	♂	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♀
1	....	1	0	3	0	2	5	0	1(1*d*)	....	....	....
2	....	1	0	1	0	1(1*d*)	2	0	2(2*d*)	....	....	....
3	....	1	0	4	5	1	1	0	3(3*d*)	....	....	....
4	....	2	0	1	3	1	1	3(1*d*)	7(6*d*)	....	....	....
5	....	4	3	8	6	3	3	1(1*d*)	1(1*d*)	....	....	....
6	....	8	7	4	5	1	0	1(1*d*)	3(3*d*)	....	....	....
7	....	2	12	3	4	3(2*d*)	2(1*d*)	3(2*d*)	2(2*d*)	....	....	....
8	....	5	9	6	7	5(2*d*)	1	1(1*d*)	3(3*d*)	1(1*d*)	6(6*d*)	....
9	....	14	15	7	5	2(1*d*)	1	1	1(1*d*)	....	....	....
10	....	6	10	2	2	1(1*d*)	4(2*d*)	0	6(6*d*)	....	....	....
11	....	6	10	3	2	2(1*d*)	0	2(2*d*)	5(5*d*)	....	....	....
12	....	9	11	5	4	7(1*d*)	7(6*d*)	1	5(5*d*)	....	....	....
13	....	10	6	2	5	3	3(3*d*)	3(3*d*)	2(2*d*)	....	....	....
14	....	9	7	7	7	1	0	1(1*d*)	2(2*d*)	....	....	....
15	....	3	3	4	5	2(2*d*)	2(2*d*)	3(2*d*)	0	0	3(3*d*)	....
16	....	6	6	7	8	2	2(2*d*)	1(1*d*)	1(1*d*)	....	....	....
17	....	7	3	6	12	2	1(1*d*)	0	0	....	....	....
18	....	5	7	9	5	3	3	0	1(1*d*)	....	....	....
19	....	6	3	12	10	5(2*d*)	8(6*d*)	2(2*d*)	1(1*d*)	....	....	....
20	....	5	4	5	5	4	3(2*d*)	0	0	....	....	....
21	....	2	5	1	7	4(1*d*)	6(5*d*)	0	0	....	....	....
22	....	0	3	8	8	3	1(1*d*)	1(1*d*)	2(2*d*)	....	....	....
23	....	4	2	3	10	3	3(3*d*)	0	0	....	....	....
24	....	3	1	7	8	4(1*d*)	2	0	0	....	....	....
25	....	0	0	10	10	2	7(5*d*)	0	0	....	....	....
26	....	2	3	8	7	2	0	0	0	....	....	....
27	....	0	0	18	21	0	5(5*d*)	0	0	....	....	....
28	....	0	1	9	9	0	0	1(1*d*)	0	....	....	....
29	....	0	2	8	3	2(1*d*)	1(1*d*)	0	0	....	....	....
30	1	1	0	9	13	1(1*d*)	0	0	1(1*d*)	1(1*d*)	....	....
31	....	1	0	5	6	....	....	0	0	....	....	1(1*d*)
	1	123	133	185	202	72(17*d*)	74(45*d*)	25(19*d*)	49(48*d*)	2(2*d*)	9(9*d*)	1(1*d*)
	69.9°	*74.5°		*73.8°		*68.4°		*59.1°		*50.3°		*44°

* Mean temperature °F. (*d*) = Dark overwintering adults.

According to table 10, the maximum period of emergence of the second brood occurred during the months of July and August. The

first adult was reared on June 30, and the last between December 16 and 31, a period of about six months during which individuals of the second brood acquired the winged stage. As the preoviposition period of the first brood was not precisely known, no record was obtained of the deposition of the first egg. The interval between the hatching of the first eggs on June 1, and the emergence of the last winged female between December 16 and 31, was about seven months. The last eggs hatched on November 12, but the nymphs died during the winter. A total of 418 males and 468 females were bred, or 50 more females than males. The following percentage of dark adults which winter over issued monthly: September, 42 per cent; October, 90 per cent; November and December, 100 per cent.

Bred from adults that flew from plains and foothills into cultivated areas.—In view of the fact that the pale green leafhoppers of the first brood flew from the plains and foothills in April and the first-brood adults from the dark females wintering in the cultivated areas emerged in May, a comparative study of the two series of life histories was undertaken. Accordingly, on April 17, 122 pale green females that flew from the plains and foothills on April 14, were collected at Hatch Station in the same beet field in which the 122 dark females were captured. The hoppers were confined in a cage enclosing a potted sugar beet for one day and then transferred to another cage. Table 11 gives a record of the egg and nymphal periods and the daily emergence of the second-brood adults.

TABLE 11

EGG AND NYMPHAL PERIODS AND DAILY EMERGENCE OF SECOND-BROOD BEET LEAFHOPPERS BRED FROM ADULTS THAT FLEW FROM PLAINS AND FOOTHILLS INTO CULTIVATED AREAS

Date of oviposition	Date of hatching	Egg period	Dates adults issued	Number of males	Number of females	Nymphal periods	Egg and nymphal periods	Mean temperature
		days				*days*	*days*	°*F*
April 17	May 5	18	May 29	2	0	24	42	67.0
....	....	....	May 30	0	1	25	43	67.1
....	....	....	May 31	1	2	26	44	68.6
....	....	....	June 1	2	1	27	45	67.5
....	....	....	June 2	1	1	28	46	67.6
....	....	....	June 3	3	0	29	47	68.0
....	....	....	June 4	1	1	30	48	68.0
....	....	....	June 5	3	0	31	49	68.2
....	....	....	June 7	1	0	33	51	68.2
				14	6			

According to table 11, the first adults issued on May 29; this cage stood next to that in which 122 pale green females of the first brood were transferred; a second-brood male acquired the winged stage on May 25, from eggs deposited April 18 to 24. The months of maximum emergence of the second-brood adults were June and July, the same months in which the largest number of first-brood adults were bred from eggs deposited by the dark females that remained in the cultivated areas during the winter.

Longevity.—A comparison was made of the length of adult life of second brood beet leafhoppers in the two series of life histories as indicated in table 12.

TABLE 12

LONGEVITY OF SECOND-BROOD ADULT BEET LEAFHOPPERS

Bred from adults that flew from plains and foothills						Bred through one brood from dark females wintering in cultivated areas					
Date	Adults alive		Date	Adults alive		Date	Adults alive		Date	Adults alive	
	♂	♀		♂	♀		♂	♀		♂	♀
May 25-	....	....	June 13–30	55	65	June 30-	....	....	Aug. 17–20	32	32
June 1	15	16	July 15	55	65	July 7	30	22	Oct. 15	11	16
July 1	13	15	Aug. 16	41	47	Aug. 1	18	13	Nov. 20	7	13
Aug. 4	10	11	Aug. 31	34	40	Aug. 20	11	11	Jan. 3	5	12
Aug. 19	7	8	Sept. 15	20	39	Sept. 15	9	11	Jan. 17	5	10
Sept. 7	3	5	Oct. 3	5	18	Oct. 2	6	10	Feb. 12	4	7
Oct. 4	1	4	Oct. 15	1	15	Dec. 1	3	8	March 3	2	6
Nov. 20	1	2	Nov. 1	0	12	Mar. 3	0	2	March 15	2	5
Jan. 3	1	0	Nov. 15		10	Mar. 15		2	March 31	1	5
Jan. 17	1		Dec. 1		8	Mar. 31		2	April 16	0	5
Feb. 12	1		Dec. 15		7	Apr. 16		1	May 1		2
March 3	1		Jan. 3		3	May 1		1	May 14		1
March 15	1		Jan. 15		2	May 14		1	June 1		0
March 31	1		Feb. 12		2	June 1		1			
April 16	1		Mar. 3		1	June 15		1			
May 1	1		Mar. 15		0	July 1		1			
May 14	0					July 15		1			
						July 27		0			

According to table 12, the second-brood adults which issued from May to August in the two series of life-histories varied as follows in respect to longest length of life:

	May 25–June 1,	June 13–30,	June 30–July 7,	August 7–20:	
Males	11	4	5	7	months
Females	5	8	12	9	months

No further details are necessary with reference to the emergence of the adults of the third, fourth, and fifth broods which were bred through successive broods from the pale green leafhoppers that flew from the plains and foothills into the cultivated areas, but the essential facts are given in table 16.

THIRD AND FOURTH BROODS

As soon as a sufficient number of second-brood adults issued, having been bred through two successive broods from eggs deposited by the dark females that wintered over in the cultivated area, they were confined in a cage enclosing a sugar beet, for the purpose of determining the emergence of the third brood. From June 30 to July 7, 1919, 30 males and 22 females were removed from two cages as they acquired the winged stage, and were transferred to a new beet about once a month until the last specimen died between July 15 and 27, 1920 (table 15). Table 13 gives a record of the emergence of the third-brood adults.

According to table 13 the maximum period of emergence of the third brood occurred during the months of September and October. The first adult was reared on August 23, and the last on February 3, a period of about 5½ months in which the third brood was acquiring the winged stage. No exact record was obtained of the deposition of the first eggs from lack of knowledge of the preoviposition period of the second brood. The interval between the hatching of the first eggs on July 22, and the emergence of the last adult on February 3, was about 6½ months. During 1919 the last eggs hatched on October 23, but the nymphs died during the winter. Eggs deposited by two second-brood females which lived through the winter were found to have hatched on March 31, 1920. A total of 183 males and 177 females were bred, or six more males than females. The following percentage of dark overwintering adults issued monthly: September, 41 per cent; October, 88 per cent; November to February, 100 per cent.

The emergence of the fourth-brood adults bred through three broods from dark adults that wintered over in the cultivated area, was determined from 19 males and 16 females of the third brood which issued from August 23 to 31 (table 13). The last female died between July 15 and 27 (table 15). Table 14 records the emergence of the fourth-brood adults.

TABLE 13

EMERGENCE OF THIRD BROOD MALE AND FEMALE BEET LEAFHOPPERS IN CULTIVATED AREA

Dates	August		September		October		November		December		January		February	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1	....	....	3	2(1*d*)	0	0	....	....	....	....	....	....	....	....
2	....	....	1	2(1*d*)	0	1(1*d*)	....	....	....	....	....	....	....	....
3	....	....	4	1(1*d*)	0	0	....	....	....	....	....	....	....	1(1*d*)
4	....	....	4(1*d*)	4(1*d*)	2(2*d*)	1(1*d*)	....	....	....	....	....	....	....	....
5	....	....	3	0	5(5*d*)	3(3*d*)	....	....	....	....	....	....	....	....
6	....	....	2(1*d*)	2(1*d*)	2(2*d*)	3(3*d*)	....	....	....	....	....	....	....	....
7	....	....	3(1*d*)	0	4(1*d*)	3(3*d*)	....	....	....	....	....	....	....	....
8	....	....	3(1*d*)	1(1*d*)	1	2(2*d*)	5(5*d*)	14(14*d*)	....	....	....	....	....	....
9	....	....	2	1(1*d*)	4(1*d*)	4(4*d*)	....	....	....	....	....	....	....	....
10	....	....	1	0	5(1*d*)	3(3*d*)	....	....	....	....	....	....	....	....
11	....	....	1	0	3(1*d*)	1(1*d*)	....	....	....	....	....	....	....	....
12	....	....	1	3(3*d*)	7(6*d*)	8(8*d*)	....	....	....	....	....	....	....	....
13	....	....	0	0	0	4(4*d*)	....	....	....	....	....	....	....	....
14	....	....	0	1(1*d*)	4(4*d*)	2(2*d*)	....	....	....	....	....	....	....	....
15	....	....	3	0	5(5*d*)	5(5*d*)	8(8*d*)	3(3*d*)	7(7*d*)	8(8*d*)	....	2(2*d*)	....	....
16	....	....	1	1(1*d*)	1(1*d*)	1(1*d*)	....	....	....	....	....	....	....	....
17	....	....	3	4(3*d*)	8(6*d*)	0	....	....	....	....	....	....	....	....
18	....	....	2	1(1*d*)	2(2*d*)	4(4*d*)	....	....	....	....	....	....	....	....
19	....	....	2	5(3*d*)	2(2*d*)	4(4*d*)	....	....	....	....	....	....	....	....
20	....	....	3	2(2*d*)	0	5(5*d*)	....	....	....	....	....	....	....	....
21	....	....	0	4(2*d*)	2(2*d*)	0	....	....	....	....	....	....	....	....
22	....	....	3	0	1(1*d*)	0	....	....	....	....	....	....	....	....
23	1	0	1	5(4*d*)	3(3*d*)	4(4*d*)	10(10*d*)	11(11*d*)	....	....	....	....	....	....
24	1	0	0	3(3*d*)	2(2*d*)	1(1*d*)	....	....	....	....	....	....	....	....
25	1	2	1	1(1*d*)	0	0	....	....	....	....	....	....	....	....
26	2	3	3	0	1(1*d*)	2(2*d*)	....	....	....	....	....	....	....	....
27	5	6	0	1(1*d*)	2(2*d*)	0	....	....	....	....	....	....	....	....
28	1	1	0	1(1*d*)	1(1*d*)	1(1*d*)	....	....	....	....	....	....	....	....
29	4	4	1(1*d*)	0	0	0	....	....	....	....	....	....	....	....
30	7	3	1(1*d*)	1(1*d*)	0	2(2*d*)	2(2*d*)	4(4*d*)	....	....	....	....	....	....
31	5	1	....	....	0	1(1*d*)	....	....	5(5*d*)	2(2*d*)	....	1(1*d*)	....	....
	27	20	52(6*d*)	46(34*d*)	67(51*d*)	65(65*d*)	25(25*d*)	32(32*d*)	12(12*d*)	10(10*d*)	....	3(3*d*)	....	1(1*d*)
	*73.8°		*68.4°		*59.1°		*50.3°		*44°		*45.9°		*49.3°	

*Mean temperature °F. (*d*) = Dark overwintering adults.

TABLE 14

EMERGENCE OF FOURTH-BROOD MALE AND FEMALE BEET LEAFHOPPERS IN CULTIVATED AREA

Dates	October		November		December		January		February		March		April	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	...	...	20(20d)	29(29d)	...	...	...	...	...	...	...	...	...	...
9	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	...	...	10(10d)	11(11d)	4(4d)	3(3d)	4(4d)	8(8d)	5(5d)	3(3d)	1(1d)	3(3d)	...	...
16	...	...	...	...	...	...	...	...	...	...	...	...	...	1
17	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18	2(2d)	0	...	...	...	...	...	...	...	...	...	...	...	...
19	1(1d)	0	...	...	...	...	...	...	...	...	...	...	...	...
20	3(3d)	1	...	...	...	...	...	...	...	...	...	...	...	...
21	1(1d)	0	...	...	...	...	...	...	...	...	...	...	...	...
22	2(2d)	2(2d)	...	...	...	...	...	...	...	...	...	...	...	...
23	1(1d)	0	10(10d)	12(12d)	...	...	...	...	...	...	...	...	...	...
24	4(4d)	1(1d)	...	...	...	...	...	...	...	...	...	...	...	...
25	5(5d)	0	...	...	...	...	...	...	...	...	...	...	...	...
26	3(2d)	5(5d)	...	...	...	...	...	...	...	...	...	...	...	...
27	4(4d)	2(2d)	...	...	...	...	...	...	...	...	...	...	...	...
28	3(3d)	0	...	...	...	...	...	...	...	...	...	...	...	...
29	2(2d)	5(5d)	...	...	...	...	...	...	1(1d)	2(2d)	...	...	...	...
30	1(1d)	3(3d)	4(4d)	1(1d)	...	...	...	...	...	...	...	...	...	...
31	1(1d)	3(3d)	...	...	4(4d)	4(4d)	...	3(3d)	...	...	1(1d)	...	...	...
	33(32d)	22(21d)	44(44d)	53(53d)	8(8d)	7(7d)	4(4d)	11(11d)	6(6d)	5(5d)	2(2d)	3(3d)	...	1
	*59.1°		*50.3°		*44°		45.9°		*49.3°		*53.4°		*59.7°	

* Mean temperature °F. (d) = Dark overwintering adults.

According to table 14, the maximum period of emergence of the fourth-brood beet leafhoppers occurred during October and November. The first adult was reared on October 18, and the last between April 1 and 16, a period of about six months in which the fourth brood was acquiring the winged stage. The period from the hatching of the first eggs on September 18, until the last adult issued between April 1 and 16, was about seven months. A total of 97 males and 102 females were bred, or five more females than males. The following percentage of dark adults which winter over issued monthly: October, 96 per cent; November to March, 100 per cent. A pale green female with two dark areas on the wing covers issued between April 1 and 16.

A high mortality in the fourth-brood nymphs occurred during the winter. In two experiments 32 to 38 per cent of the nymphs succumbed during the winter. The cages were protected from rains, in a large tent with movable sides which were opened in fair weather so that the hoppers were exposed to the sunshine.

Longevity.—Beet leafhoppers bred in the two series of life-history studies were used to determine the longevity of the third and fourth-brood adults. The third-brood insects were reared through two successive broods from eggs deposited by the dark females, and the fourth-brood specimens were bred through successive broods from leafhoppers which flew from the plains and foothills. The length of adult life in each case is indicated in table 15.

TABLE 15

LONGEVITY OF THIRD- AND FOURTH-BROOD ADULT BEET LEAFHOPPERS

Date	Third-brood adults alive		Date	Fourth-brood adults alive	
	♂	♀		♂	♀
Aug. 23–31	19	16	Aug. 26–31	14	16
Oct. 3	17	14	Oct. 3	11	15
Dec. 1	17	11	Nov. 1	6	9
March 3	4	10	Nov. 15	5	9
March 15	3	9	Dec. 1	5	8
March 31	2	6	Dec. 15	4	8
April 16	2	5	Jan. 3	3	7
May 1	0	5	Jan. 15	0	5
May 14	....	5	Feb. 12	....	5
June 1	....	3	March 3	....	5
June 15	....	1	March 15	....	5
July 1	....	1	March 31	....	4
July 15	....	1	April 16	....	3
July 27	....	0	May 1	....	0

The results in table 15 show that some of the third and fourth-brood males lived 7½ and 4 months, and the females, 11 and 8 months respectively.

COMPARISON OF DEVELOPMENT OF BROODS OF BEET LEAFHOPPERS IN TWO LIFE-HISTORIES

Table 16 gives a comparison of the development of four broods of beet leafhoppers bred through successive broods from eggs deposited by the dark adults that wintered in the cultivated areas with the second to the fifth-brood adults reared from eggs deposited by the first generation that flew from the plains and foothills into the cultivated areas.

TABLE 16

COMPARISON OF DEVELOPMENT OF BROODS IN TWO SERIES OF LIFE-HISTORIES

Bred from Dark Females Wintering in Cultivated Areas

Brood	Date of first hatching	Date first adult issued	Months of maximum emergence
First	April 7	May 2	June–July
Second	June 1	June 30	July–Aug.
Third	July 22	Aug. 23	Sept.–Oct.
Fourth	Sept. 18	Oct. 18	Oct.–Nov.

Bred from Pale Green Adults that Flew from Plains and Foothills into Cultivated Areas

Brood	Date of hatching	Date first adult issued	Months of maximum emergence
Second	May 1	May 25	June–July
Third	June 18	July 10	July–Aug.
Fourth	July 31	Aug. 26	Sept.–Oct.
Fifth	Sept. 16	Oct. 19	Oct.–Nov.

OVERWINTERING ADULTS

Yellow leafhoppers, which issued during October, wintered over in cages without depositing eggs during the autumn but the number of specimens was limited to a single female of the second brood which emerged on October 4 (table 10) and another adult of the fourth brood which issued on October 20 (table 14). Eggs were deposited, however, during late summer and early autumn by yellow females of the first three broods bred August 1 to September 25 (tables 7, 10, 13)

and by the fourth brood reared from August 26 to September 14, and bred through successive broods from the pale green adults that flew from the plains and foothills.

Pale yellow adults rarely winter over on the plains and foothills. It was evident from dissection that some yellow females wintered over without depositing eggs during the autumn. Of eighteen specimens collected from October 16 to January 16 during three seasons, eleven had no mature eggs in the ovaries while seven females were at the egg-laying stage as indicated in table 17.

TABLE 17

NUMBER OF YELLOW FEMALE BEET LEAFHOPPERS WITH MATURE EGGS IN THE OVARIES COLLECTED ON PLAINS AND FOOTHILLS OF COAST RANGE OF THE SAN JOAQUIN VALLEY

Locality	Plant	Date	Number of yellow females dissected	Mature eggs in ovaries
Wild Cat Canyon, west of Oro Loma (*M*)	Perennials	Oct. 16/19	2	1
Plains, 5 miles north of Tijon Pass (*S*)	*Erodium cicutarium*	Dec. 13/18	5	1
Foothills, 13 miles southwest of Tracy (*N*)	*E. cicutarium*	Dec. 24/18	1	0
Ingram canyon, 7 miles southwest of Vernalis (*N*)	*E. cicutarium*	Dec. 26/19	3	1
Wild Cat canyon (*M*)	*E. cicutarium*	Dec. 27/19	3	1
Wild Cat canyon (*M*)	*E. cicutarium*	Jan. 16/20	4	3
			18	7

(*N*) northern, (*M*) middle, (*S*) southern, San Joaquin Valley.

When the dark overwintering beet leafhoppers first make their appearance in the cultivated areas, it is often difficult and sometimes impossible to distinguish dark and yellow males owing to faintness of the dark areas on the wing covers. After the flights to the plains and foothills have occurred, dark males are easily distinguished during the winter. Dark females can be determined with certainty in the cultivated regions and on the plains and foothills during the autumn and winter.

A remarkable peculiarity of each brood in the two series of life-histories was the fact that dark adults which wintered over appeared during the autumn and winter. A comparison of the monthly percentages of dark females of the four broods which were bred during

1919 and 1920, with those of specimens captured in the cultivated areas, plains, and foothills from 1918 to 1921, is indicated in table 18.

Preoviposition period.—A total of 6.026 beet leafhoppers was obtained from the four broods and only two dark females issued before September. These specimens were confined in a cage enclosing a sugar beet together with two pale yellow males. No eggs were deposited by the bugs during the summer and autumn; on December 1 they were dissected but no fully developed eggs were found in the ovaries.

TABLE 18

COMPARISON OF MONTHLY PERCENTAGES OF DARK FEMALE BEET LEAFHOPPERS OF FOUR BROODS WHICH WERE BRED DURING 1919 AND 1920, WITH MONTHLY PERCENTAGES OF DARK FEMALES CAPTURED IN CULTIVATED AREAS AND ON PLAINS AND FOOTHILLS OF COAST RANGE OF THE SAN JOAQUIN VALLEY FROM 1918 TO 1921

Month	Percentage of dark overwintering females bred in cages					Percentage dark overwintering females collected in cultivated areas	Percentage dark overwintering females collected on plains and foothills
	First brood	Second brood	Third brood	Fourth brood	Average		
August	1.0	....	....	....	1.0	....	....
September	40.9	60.8	73.9	....	58.5	71.3	....
October	100.0	97.9	100.0	95.4	98.3	98.5	95.6
November	....	100.0	100.0	100.0	100.0	98.4	100.0
December	....	100.0	100.0	100.0	100.0	100.0	97.9
January	....	....	100.0	100.0	100.0	100.0	98.1
February	....	....	100.0	100.0	100.0	100.0	100.0
March*	....	....	....	100.0	100.0	96.6	100.0
April*	....	....	....	....	....	100.0	....

* Northern San Joaquin Valley.

An attempt was made to determine approximately the preoviposition period of dark females of five broods which issued from August to December in the cultivated areas at Manteca. Table 19 shows that from 3 to 5 months elapsed before fully developed eggs appeared in the ovaries of the dark overwintering adults.

During 1919–1921 dark females wintering in the cultivated areas and on the plains and foothills were dissected to determine when fully developed eggs were present in the ovaries. During October, November, and December no mature eggs were present in the ovaries of dark adults collected in the cultivated areas and the dark females were not at the egg-laying stage during October and November on the plains and foothills of the Coast Range of the San Joaquin Valley.

TABLE 19

PREOVIPOSITION PERIODS OF FIVE BROODS OF DARK FEMALES WINTERING IN CULTIVATED AREAS

Dates of emergence of adults	Brood	Number of females	Date dissected	Number of adults with ripe eggs in ovaries	Preoviposition period months
Aug. 19	First	2	Dec. 1	0	......
Sept. 4–26	First	7	Dec. 1	1	3
Sept. 7–29	Second	36	Dec. 15	0	......
Sept. 1–30	Third	25	Jan. 1	0	......
Sept. 6–22	Fourth	22	Jan. 15	0	......
Oct. 4–23	First	4	March 3	1	5
Oct. 1–30	Second	31	Feb. 15	1	4½
Oct. 2–31	Third	51	Feb. 15	0	......
Oct. 22–31	Fourth	19	Jan. 15	0	......
Oct. 21–29	Fifth	11	Jan. 1	0	......
Nov. 1–15	Second	6	March 3	5	4
Nov. 1–30	Third	29	March 15	20	4½
Nov. 1–30	Fourth	37	March 15	27	4½
Nov. 1–30	Fifth	3	March 15	2	4½
Dec. 1–31	Third	7	March 15	6	3½
Dec. 1–31	Fourth	3	March 15	3	3½
Dec. 1–31	Fifth	4	March 15	1	3½

Dissections of dark overwintering females captured on the plains near the Tehachapi Mountains in the southern portion of the San Joaquin Valley showed a higher percentage of dark females with ripe eggs in the ovaries in December (24%) than in the middle and northern parts of the valley (4%). During the middle of January 64 per cent of the dark females were at the egg-laying stage in a canyon situated in the middle part of the San Joaquin Valley, compared with 52 per cent in the northern portion of the valley. In February 86 to 99 per cent of the dark females had full-grown eggs in the ovaries in the northern part of the valley. Table 20 shows the percentage of dark females with mature eggs in the ovaries.

The preoviposition period of the dark overwintering females can be determined approximately under natural conditions. According to table 18, the dark adults were abundant in the cultivated areas from September to November and if egg-laying began from December to February (table 20), respectively, then the preoviposition period would be about four months.

TABLE 20

RESULTS OF DISSECTIONS OF DARK OVERWINTERING FEMALE BEET LEAFHOPPERS COLLECTED ON VARIOUS PLANTS TO DETERMINE WHEN EGG-LAYING BEGINS IN CULTIVATED AREAS AND ON PLAINS AND FOOTHILLS OF COAST RANGE OF THE SAN JOAQUIN VALLEY

Locality	Plants	Date dark females were collected	Number of dark females dissected	Percentage of females with ripe eggs in ovaries
	Cultivated areas			
Oro Loma (*M*)	*Salsola kali tenuifolia*	Oct. 16, '19	50	0
Corcoran (*S*)	*Atriplex argentea expansa*	Oct. 22, '19	49	0
Connor (*S*)	*A. argentea expansa* and *A. bracteosa*	Oct. 23, '19	4	0
Lerdo (*S*)	*S. kali tenuifolia*	Oct. 23, '19	4	0
Oro Loma (*M*)	*A. semibaccata*	Nov. 11, '19	49	0
Wasco (*S*)	*A. semibaccata*	Dec. 14, '18	25	0
Manteca (*N*)	Sugar beets	Dec. 26, '18	31	0
Wasco (*S*)	*A. semibaccata*	Feb. 16, '18	8	100
Hatch Station (*N*)	Sugar beets	March 4, '19	49	100
	Plains and foothills			
Plains west of Oro Loma (*M*)	Perennials	Oct. 16, '19	31	0
Wild Cat Canyon, west of Oro Loma (*M*)	Perennials	Nov. 11, '19	50	0
Canyon, 13 miles southwest of Tracy (*N*)	*Erodium cicutarium*	Nov. 13, '18	29	0
Ingram Canyon, 7 miles southwest of Vernalis (*N*)	Perennials	Nov. 21, '19	25	0
Plains, 5 miles north of Tijon Pass (*S*)	*E. cicutarium*	Dec. 13, '18	25	24
Canyon, 13 miles southwest of Tracy (*N*)	*E. cicutarium*	Dec. 24, '18	59	20
Ingram Canyon (*N*)	*E. cicutarium*	Dec. 26, '19	100	4
Wild Cat Canyon (*M*)	*E. cicutarium*	Dec. 27, '19	100	4
Ingram Canyon (*N*)	*E. cicutarium*	Jan. 15, '20	100	52
Wild Cat Canyon (*M*)	*E. cicutarium*	Jan. 16, '20	100	64
Ingram Canyon (*N*)	*E. cicutarium*	Feb. 11, '20	100	86
Corral Hollow, 8 miles southwest of Tracy (*N*)	*E. cicutarium*	Feb. 23, '21	100	99

(*N*) northern, (*M*) middle, (*S*) southern, San Joaquin Valley.

Longevity.—The longevity of the dark overwintering adults can be determined under natural conditions. Dark specimens first make their appearance in August in the cultivated areas and are abundant from September to November (table 18). The first marked reduction in the number of dark females occurs during March and early April on the plains and foothills. In all probability the last dark females are at the end of their natural life by the time that the pasture vegetation becomes dry. It is doubtful whether any dark females which flew to the plains and foothills during the autumn, returned to the cultivated areas during the spring. The length of adult life of the dark females is probably not more than 7 or 8 months under field conditions.

If the longevity of the dark overwintering adults under natural conditions is compared with the results obtained by confining the leafhoppers in cages, it is evident that the life of some adults is prolonged greatly beyond the natural length. The last dark female of the 122 specimens collected in a beet field at Hatch Station on February 12, died on September 3, but under natural conditions dark females which wintered over in the cultivated areas were not taken after the cessation of the spring flights of the pale green adults from the plains and foothills. A comparison of the longevity of the dark females under natural conditions with some of the pale green and yellow leafhoppers of the four broods (tables 9, 12, 15) bred in cages shows that the length of adult life of the pale green and yellow adults in captivity is also greatly prolonged. As already stated, the preoviposition period of the dark females requires about four months under natural conditions or 3 to 5 months in cages. If this time is deducted from their longevity of 7 to 8 months, one would be inclined to believe that the remainder of 3 to 4 months would be equivalent to the average length of life of the pale green and yellow adults after oviposition begins, providing that temperature conditions were the same. In the case of the first-brood adults the preoviposition period is short (table 8) and, as the temperature becomes higher during the summer, the average length of adult life of the spring and summer broods in the cultivated areas is probably even shorter.

Males die during winter.—During the winter a reduction in the number of males occurred and dead specimens were occasionally obtained in the insect net by sweeping perennial plants on which the sexual behavior, described in a previous paper,[6] was observed during

November. In determining the life-history, the proportion of sexes was found to be about equal; 3,011 males and 3,015 females were bred in the four broods. A comparison of the percentages of male and female beet leafhoppers captured in the cultivated areas and on the plains and foothills of the Coast Range is shown in table 21.

TABLE 21

PERCENTAGE OF MALE AND FEMALE BEET LEAFHOPPERS COLLECTED IN CULTIVATED AREAS AND ON PLAINS AND FOOTHILLS OF THE COAST RANGE OF THE SAN JOAQUIN VALLEY

1918–1921 month	Cultivated areas		Plains, foothills	
	♂ %	♀ %	♂ %	♀ %
September	65.4	34.5		
October	47.4	52.5	59.4	40.5
November	55.2	44.7	59.1	40.8
December	38.0	62.0	12.1	87.8
January			4.8	95.1
February	.8	99.1	1.4	98.5
*March	.7	99.2		100.0
*April		100.0		

* Northern San Joaquin Valley.

It is evident from table 21 that the first marked reduction in the number of dark males occurred during December in both the cultivated areas and on the plains and foothills, and that from February to March dark males were rarely taken.

NUMBER OF GENERATIONS

The breeding experiments in cages gave no clue to the number of generations which occur under field conditions. One difficulty was that the length of adult life is greater than occurs under natural conditions. It is evident in the two series of life-histories conducted in cages, that the minimum period of the development of each brood was ascertained, but the average or maximum periods of each brood was not determined.

According to Ball[8]

the measure of a generation includes the preoviposition period, including mating time, period of egg deposition, egg and nymphal stages. If mating is observed in abundance a new generation will soon follow. This is the time when flights

occur, migration takes place, and at that time males often fly to lights in numbers. In the cases of adult hibernation the fall generation does not mate and no eggs develop that season.

The congregation of large numbers of adults on favorable breeding plants and the pairing of the sexes was frequently observed in California. After the pasture vegetation begins to dry on the foothills, large numbers of spring brood adults usually congregate near the mouth of Little Panoche Pass during April, and mating occurs at sunset. It is evident that the progeny which develops from eggs deposited by the dark overwintering adults represents the first or spring generation (fig. 11). In years with late spring rains, a partial second brood may develop during May and June on the plains and foothills.

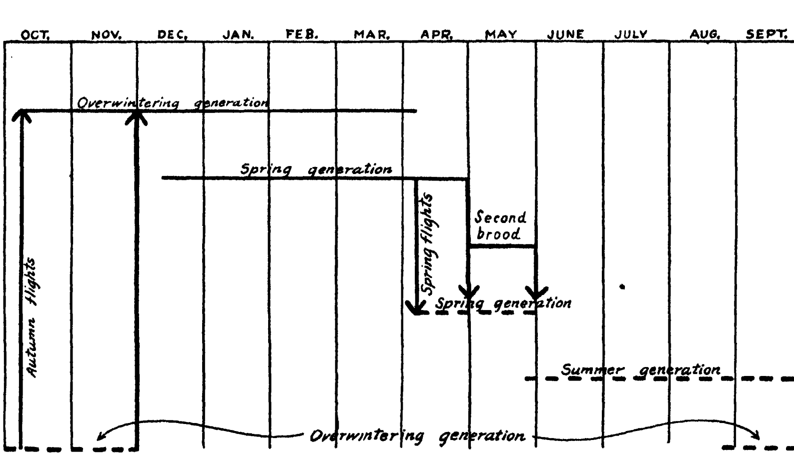


Fig. 11. Chart showing number of generations and spring and autumn flights of the beet leafhopper in the San Joaquin Valley.

———— Plains and foothills. - - - - - Cultivated areas.

During the 1919 outbreak of the beet leafhopper an enormous congregation of pale yellow adults was observed on June 26, on bractscale (*Atriplex bracteosa*) (figs. 12, 13, 14, 15) growing among diseased sugar beets and along the margin of the fields in the vicinity of Hatch Station.[10] The foliage of these saltbushes was covered with droplets of clear excrement which glistened in the sunshine. When a person walked past one of these weeds, so that a shadow was thrown on the plant, a swarm of leafhoppers flew up. Nymphs were still abundant on sugar beets with green innermost leaves and dried outer foliage. The next visit to these beet fields on July 5, showed that most of the insects had left the saltbushes and a summer migration had occurred.

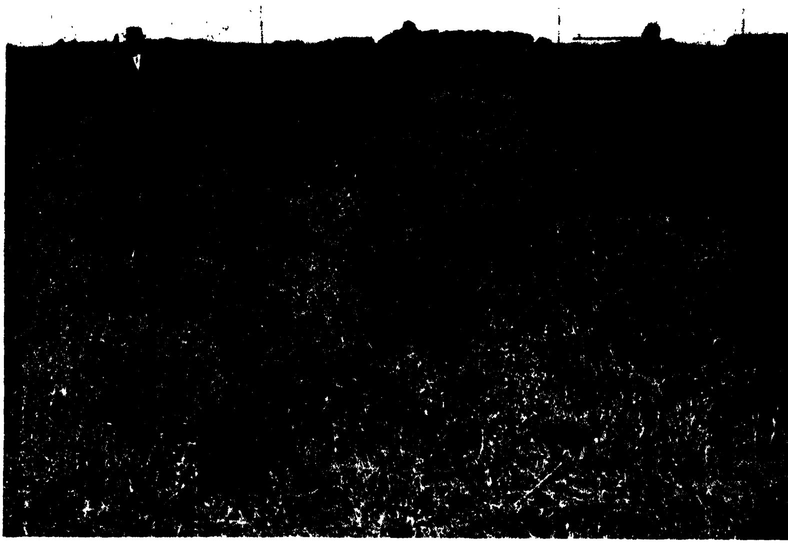


Fig. 12. Vacant field covered with bractscale (*Atriplex bracteosa*). This annual saltbush forms dense pure communities in the San Joaquin Valley, and owing to its size and abundance, is one of the most important food and breeding plants of the beet leafhopper in the cultivated areas of California. The leafhoppers are commonly found on this weed from the time that the spring dispersal from the plains and foothills until the return flights occur.

Fig. 13. Bractscale (*Atriplex bracteosa*) showing height of plant which may vary from 1 to 5 feet and with stems commonly spreading to form dense tangled mats from 1 to 10 feet across, from which arise slender erect or ascending twigs.

Another assemblage of the pale yellow leafhoppers was observed on bractscale on July 26.[10] If the enormous congregations and mating of the beet leafhoppers can be considered as an indicator of a new generation, then this would constitute the second or summer generation (fig. 11). The foliage of the diseased beets were mostly dry and no marked increase of the hoppers occurred in these fields.

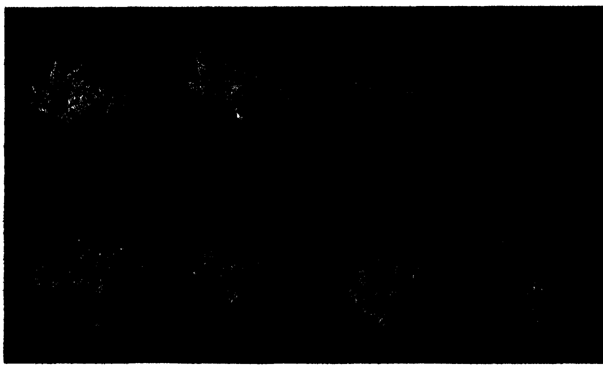


Fig. 14. Fruiting bracts of bractscale (*Atriplex bracteosa*). These structures have been almost universally considered as modified leaves enclosing the seeds.

Fig. 15. Fruiting bracts of wheelscale (*Atriplex elegans*).

The third or autumn generation represents the dark overwintering forms which acquired the winged stage on favorable weeds from August to December (fig. 11). The third generation may fluctuate in numbers according to the food supply available during the autumn. During 1918 heavy rains fell on September 11 to 13, in the San Joaquin Valley, germinating the seeds of the pasture vegetation, and a new growth of weeds developed in the cultivated areas. During the autumn the saltbushes and other favorable breeding plants of the leafhopper normally become dry and the nymphs which hatched from

eggs deposited in the fall by the females of the summer generation now found an abundance of food in this new growth of vegetation in the cultivated territories. Many of the nymphs acquired the winged stage subsequent to October and November after the return flight of the dark winter adults to the plains and foothills. During the winter these stragglers which remained behind in the cultivated districts congregated on the very earliest planted beets in the northern part of the San Joaquin Valley and one-half of the 1919 crop showed curly-top symptoms before the enormous numbers of pale green leafhoppers of the spring brood flew from the plains and foothills into the cultivated regions during April.[10]

Attention has already been called in this paper to the fact that the dark overwintering adults mate during the autumn on the plains and foothills and that the males die during the winter.

The beet leafhopper is rarely attracted to lights, and when such flights occur, the females (85.2%) greatly outnumber the males (14.7%). Two flights occurred to electric lamps at Coalinga on July 15 and August 3, 1918,[6] but these flights have no bearing on the number of generations.

In the Imperial Valley large numbers of Jassids were attracted on calm evenings to electric lamps in cantaloupe packing sheds. The sexual behavior and the relation of flights of the beet leafhopper to lights was studied from June 3 to 15. An enormous congregation of nymphs and adults had occurred on nettle-leaf goosefoot (*Chenopodium murale*) (fig. 16) from dried wheelscale (*Atriplex elegans*) (fig. 15). A single female beet leafhopper was attracted to an electric light on June 7, but not another specimen was taken from June 8 to 15.[6]

DISCUSSION

The statement that "the number of generations a year will vary in different parts of the country according to the various climates and is likely to fluctuate from year to year in accordance with seasonal variations"[8] is correct in so far as the beet leafhopper is concerned.

According to Ball[3] the number of generations in the Hemiptera is not

> mere adjustments to a temporary excess of heat or cold, moisture or dryness, but rather are deep-seated and fixed modifications brought about through reaction to seasons unnumbered whose means, at least within the limits of the present geological periods, are constants. Such adaptations as these are not to be overthrown

by the influence of an early season or a late one, a heavy rainfall, or even an arid condition. They are merely modified in detail, but these modifications only serve to emphasize the fixity of the underlying principle.

Fig. 16. Nettle-leaf goosefoot (*Chenopodium murale*) which is a favorable food and breeding plant of the beet leafhopper in the cultivated areas. Left, branch of healthy plant; upper right, parts of plant affected with curly top showing curled leaves; lower right, leaf showing blister-like elevations, a symptom of the disease.

According to Ball(2) *Eutettix tenellus* (Baker) is a "single brooded species." He shows graphically the average time of appearance of the nymphs and adults in different states including Arizona, California, western Colorado, and Utah. In his life-history chart, Ball indicates

that the adults make their appearance on beets in March and the nymphs are present from May to July in the San Joaquin Valley and from May to August in the Salinas Valley of California.

The statement that the beet leafhopper is a "single-brooded species" is not correct. It is evident that the number of generations of the beet leafhopper is not fixed by inheritance since the majority pass through two generations in the fog belt and three generations occur annually in the San Joaquin Valley.

Ball's statements concerning the dates of the appearance of nymphs and adults on beets in the San Joaquin and Salinas valleys are also incorrect. The first large flights from the plains and foothills into the cultivated areas usually occur in April in the San Joaquin Valley. Records kept by the Spreckels Sugar Company since 1910, show that the spring flights into the beet fields of the Salinas Valley occurred during April or May except in 1925. During the 1925 outbreak of the beet leafhopper, the spring dispersal in the San Joaquin Valley began on March 29, and spring-brood adults were found on beets in the Salinas Valley on March 24 to 26.

First-brood nymphs which develop from eggs deposited by the dark adults wintering in the cultivated areas first appear in the beet fields during April in the San Joaquin and Salinas valleys. During the 1919 and 1925 outbreaks of the beet leafhopper, when many fields of beets were not harvested, nymphs were present during the winter in both valleys.

SUMMARY

The incubation periods varied from 11 to 55 days from February to October, the nymphal periods of the first brood from 23 to 37 days from April to October, and the egg and nymphal periods combined from 37 to 99 days. Eggs deposited from November 1 to January 15 failed to hatch, or the nymphs died out-of-doors. During the winter there was a high mortality of the nymphs which hatched from eggs deposited during September and October.

The average egg-laying capacity of five females was 350 eggs. The eggs do not develop without fertilization.

Four broods were bred in cages from the dark females wintering in the cultivated areas of the San Joaquin Valley. After the flight of the pale green adults of the first generation from the plains and foothills into the cultivated areas, four more broods were also reared in cages. The months of maximum emergence of the first to fourth broods bred from the dark females were the same as those in which

the second to the fifth broods were reared from the pale green leafhoppers as follows: June–July, July–August, September–October, and October–November. The minimum period of the development of each brood was determined in the two series of life-histories, but not the average or maximum periods of each brood.

Three generations of the beet leafhoppers occur in the San Joaquin Valley. The progeny which develops from eggs deposited by the dark adults wintering on the plains and foothills represents the first or spring generation. In years with late spring rains, a partial second brood may develop during May and June on the plains and foothills. Large numbers of pale green adults usually congregate near the entrance of Little Panoche Pass during April and mating occurs at sunset. A second or summer generation develops in the cultivated areas; congregations of enormous numbers of leafhoppers, mating, and migrations occurred from June 26 to July 26, 1919. The autumn or third generation represents the dark adults, most of which fly to the plains and foothills during the autumn and mate.

The minimum preoviposition period of first-brood adults was three days during July at a mean temperature of 80.3° F. The preoviposition period of the dark overwintering females varied from three to four and one-half months, hence no eggs were deposited during the autumn. The following percentages of dark females collected during the winter on the Coast Range had fully developed eggs in the ovaries: December, 4 per cent; January, 52–64 per cent; February, 86–99 per cent.

The longevity of the dark overwintering females is seven or eight months under natural conditions. The length of adult life is greatly prolonged in cages.

Yellow adults rarely winter over. Some specimens collected on the plains and foothills from October to January had mature eggs in the ovaries; while others, like the dark females, winter over without depositing eggs during the autumn.

The dark males follow the females to the plains and foothills, mate during the autumn, and die during the winter. During the spring, however, most of the pale green males of the spring broods remain behind on the plains and foothills and probably die after the pasture vegetation becomes dry. After a flight had occurred during the spring, 8 per cent of the specimens collected in the cultivated areas were males and 92 per cent were females. After the invasion of the spring-brood adults into the cultivated areas, 92 per cent of the females had mature eggs in the ovaries.

LITERATURE CITED

[1] BALL, E. D.
1907. The genus Eutettix with especial reference to the beet leafhopper. Proc. Davenport Acad. Sci., **12**:27–94.

[2] BALL, E. D.
1917. The beet leafhopper and the curly leaf disease that it transmits. Utah Agr. Exp. Sta., Bul. **155**:1–56.

[3] BALL, E. D.
1920. The life cycle in Hemiptera. Ann. Ent. Soc. America, **13**:142–151.

[4] HAEGELE, R. W.
1927. The beet leafhopper (*Eutettix tenellus* Baker). Idaho Agr. Exp. Sta., Bul. **156**:1–28.

[5] KNOWLTON, G. E.
1928. The beet leafhopper in Utah. A study of its distribution and occurrence of curly top. Utah Agr. Exp. Sta., Bul. **205**:1–23.

[6] SEVERIN, H. H. P.
1919. Notes on the behavior of the beet leafhopper (*Eutettix tenella* Baker). Jour. Econ. Ent., **12**:303–308.

[7] SEVERIN, H. H. P.
1919. Investigations of the beet leafhopper (*Eutettix tenella* Baker) in California. Jour. Econ. Ent., **12**:312–326.

[8] SEVERIN, H. H. P.
1921. Summary of life history of beet leafhopper (*Eutettix tenella* Baker), Jour. Econ Ent., **14**:433–436.

[9] SEVERIN, H. H. P.
1922. The life history of the beet leafhopper. A record from studies of *Eutettix tenella* conducted in the San Joaquin Valley, California. Facts About Sugar, **14**:92–93; 110–111; 130–131; 152–154, 158; 170–171.

[10] SEVERIN, H. H. P.
1924. Causes of fluctuation in numbers of beet leafhoppers (*Eutettix tenella* Baker) in a natural breeding area of the San Joaquin Valley in California. Jour. Econ. Ent., **17**:639–645.

[11] SEVERIN, H. H. P.
1925. A natural breeding area of the beet leafhopper (*Eutettix tenella* Baker) in the Sierra Nevada Mountains. Jour. Econ. Ent., **18**:730–733.

[12] SEVERIN, H. H. P.
1926. The 1925 outbreak of the beet leafhopper (*Eutettix tenella* Baker) in California. Jour. Econ. Ent., **19**:478–483.

[13] STAHL, C. F.
1920. Studies on the life history and habits of the beet leafhopper. Jour. Agr. Res., **20**:245–252.

PLATE 1

Nymphs of Beet Leafhopper, *Eutettix tenellus* (Baker)

Fig. *a*. First nymphal instar: upper, recently hatched nymph; lower, nymph previous to first molt.

Figs. *b–f*. Second to sixth nymphal instars one day after each molt showing color pattern.

Fig. *g*. Nymph previous to molting showing membraneous connections between the head and thorax and abdominal segments greatly stretched.

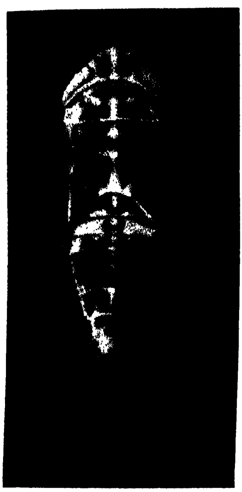
Figs. *h–j*. Nymphs showing color variations.

a

b

c

d



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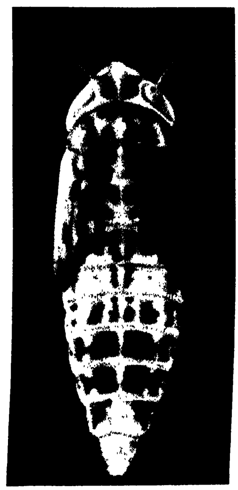

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PLATE 2

Adults of Beet Leafhopper, *Eutettix tenellus* (Baker)

Figs. *a–c*. Spring brood adults with pale green vertex and pronotum. Adults which acquire the winged stage on the plains and foothills during March and early April have dark markings on the elytra, those that pass through the last molt later in the spring have no markings on the wing covers.

Figs. *d, e*. Summer brood adults with pale yellow or lemon vertex and pronotum.

Figs. *f–l*. Dark overwintering adults showing color variations.

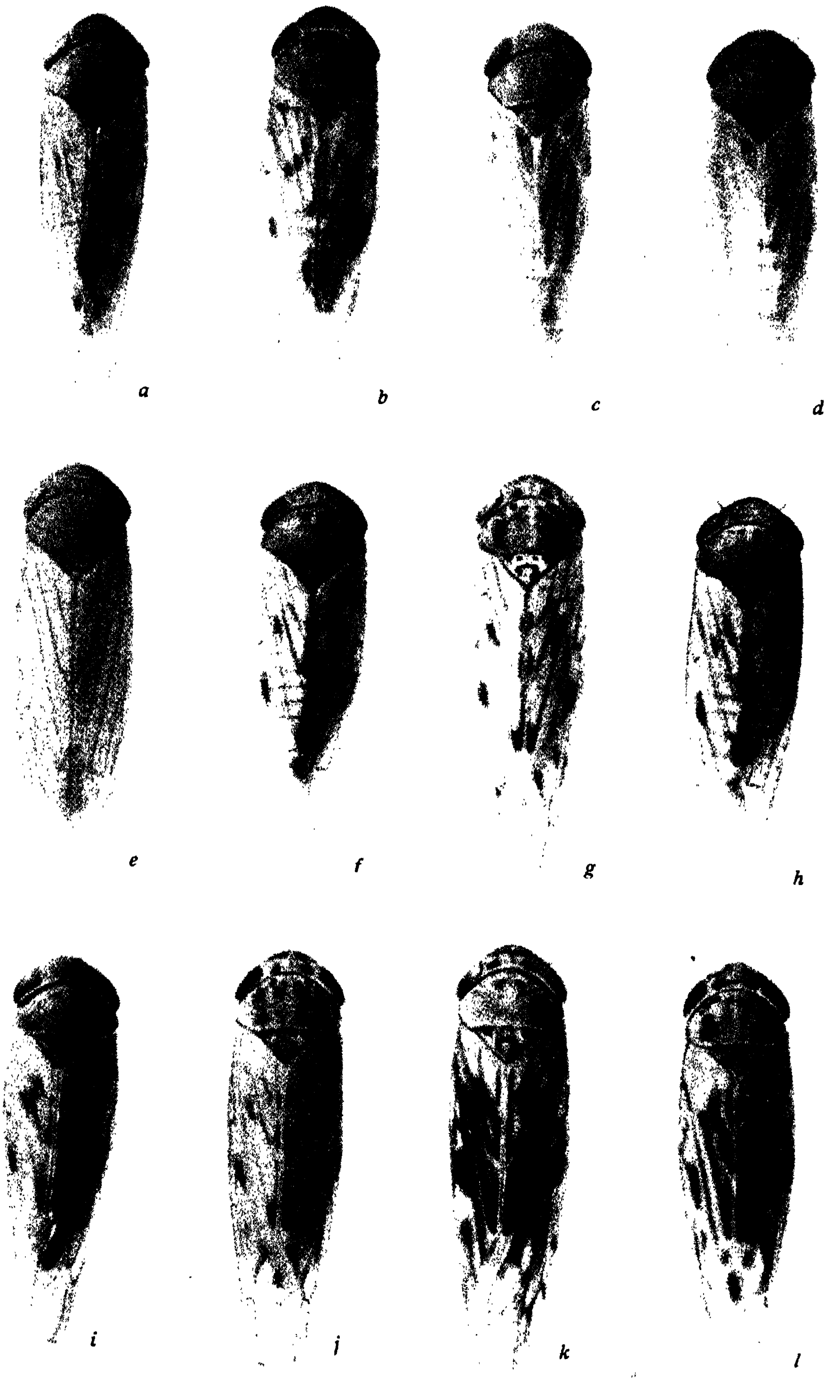
a
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PLATE 3

Eggs and process of hatching of Beet Leafhopper, *Eutettix tenellus* (Baker)

Fig. *a.* Eggs deposited in petiole of sugar beet leaf.

Fig. *b.* Eggs removed from petiole a few days after deposition.

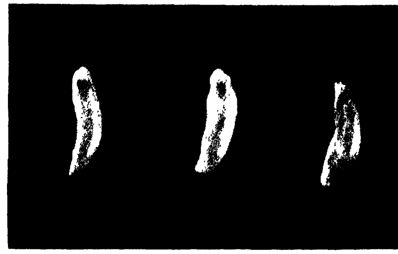
Fig. *c.* Eggs nearing the hatching period, showing pink eyes.

Fig. *d.* Nymph enclosed in chorion, amniotic and vitelline membranes issuing from egg-slit in petiole.

Figs. *e–f.* Nymphs after extrication from embryonic membranes.

Fig. *g.* Nymph ready to crawl away. Nymphs during the process of hatching as in figures *d–f*, when transferred with a camel's hair brush from a curly top to a healthy beet, failed to produce the disease.

a



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d

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PLATE 4

Miscellaneous photographs of Beet Leafhopper, *Eutettix tenellus* (Baker)

Figs. *a*, *b*. White adults after last molt showing wings before and after expansion.

Fig. *c*. Nymph shedding its skin.

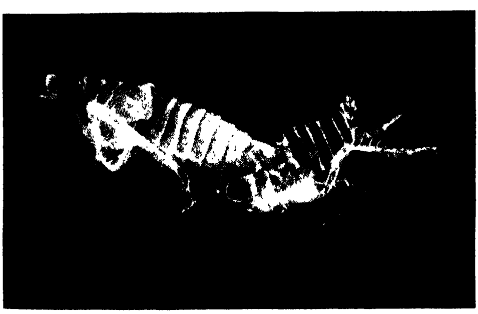
Fig. *d*. Plates at the end of the abdomen distinguish the male from other species.

Figs. *e*, *f*. Beet leafhoppers in coition.

Fig. *g*. Semi-circular emargination of the last ventral segment of the abdomen distinguishes the female from other species.

a

b



c

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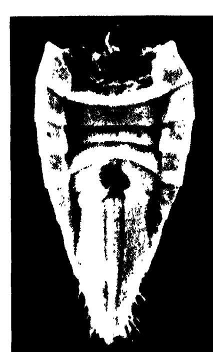

g

A STUDY OF THE IMMATURE FORMS OF SOME CURCULIONIDAE (COLEOPTERA)

BY

RALPH ELLIOTT BARRETT

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INTRODUCTION

Curculionid larvae are often responsible for serious injuries to field and truck crops, but correct determination of exact species is often impossible unless the imago is also taken, and even this is not always conclusive. With the introduction and rapid spread of such weevils as the vegetable weevil, *Listroderes obliquus* Gyll., and the strawberry root weevils, it is highly advisable for the entomologist to be able to determine the larvae. An attempt has therefore been made in this paper to characterize some of the more commonly encountered and important curculionid larvae.

ACKNOWLEDGMENTS

I am indebted to Professor E. O. Essig, Mr. Leslie M. Smith, and the United States National Museum for generous loans and gifts of material.

I am also deeply indebted to Professor E. O. Essig and Dr. E. C. Van Dyke for many helpful suggestions and criticisms.

Pantomorus godmani (Crotch)

Figures 1, 7, 13, 19

This is a widespread species probably introduced from Mexico. It is commonly known in economic literature as Fuller's rose weevil. The larvae live in the soil and feed on roots while the adults feed on leaves, flowers, and buds of alfalfa, apple, apricot, common and lima beans, blackberry, chrysanthemum, currant, grape fruit, lemon, oaks,

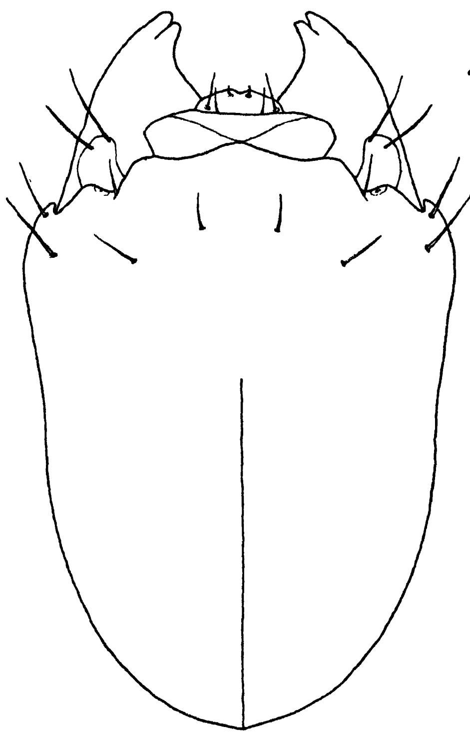

Fig. 1. *Pantomorus godmani* (Crotch), dorsal view of head of larva.

orange, peach, pear, pepper, plum, prune, potato, raspberry, roses, strawberry, and many other plants. Pupation occurs in a small cell in the soil. The species occurs throughout most of North America and is a common pest in California.

LARVAE—

Head chitinized; distinctly longer than wide.
Epicranial stem indistinct, epicranial arms wanting.
Frons and epicranium bearing ten setae.
Clypeus transverse, with triangular indentation which the epistoma fills.

Labrum broader than long; bearing on dorsal surface four setae.

Epipharynx bearing sixteen setae or sense cones of varying lengths, the surface is also rather densely studded with very minute spines or bristles.

Ocelli wanting.

Antennae located at anterior margin of frons.

Mandibles rather stout, triangular, distinctly bifid at apex; dorsal surface with two setae; apex jet black.

Maxilla with cardo distinct and simple; mala at apex obtuse, ventral surface smooth, dorsal surface with longitudinal row of eight setae; maxillary palpus extending by one-half its own length beyond mala, two-segmented, terminal segment with approximately six small terminal setae, basal segment with three large setae two dorsal and one ventral, palpifer with single setae.

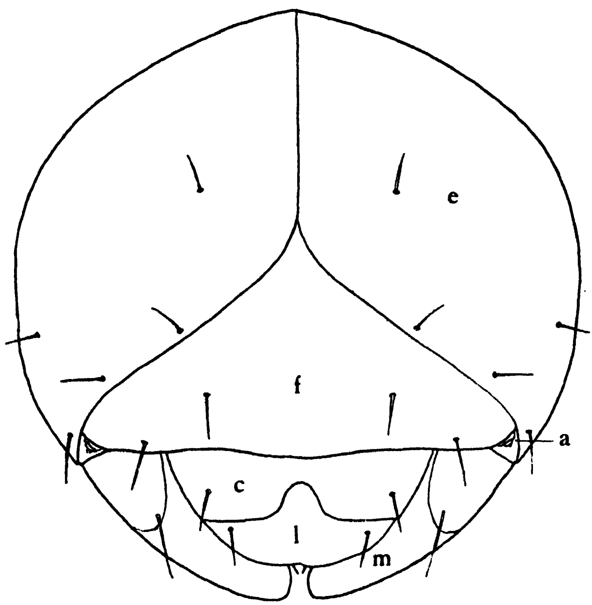

Fig. 2. *Brachyrhinus sulcatus* (Fab.), dorsal view of head of larva: *a*, antenna; *c*, clypeus; *e*, epicranium; *f*, front; *l*, labrum; *m*, mandible.

Ligula slightly bilobed, membraneous.

Labrum membraneous, labial palpa one and one-half times as long as first segment of maxillary palpus.

Mentum chitinous, with three prominent anterior projections and one posterior projection as in the genus *Brachyrhinus*.

Gula rather large, subtriangular.

Thorax and abdomen with prominent setae.

Spiracles lateral, with oval openings.

Color white, tips of mandibles and setae brown.

Length of mature larvae 8 mm.

Specimens studied from San José, California.

GENERIC CHARACTERS OF *Brachyrhinus* LARVAE FOUND IN THE UNITED STATES

Head reddish-brown, slightly longer than wide, sides arcuate, junction of epicranial stem and apex forming triangular incision.

Epicranial stem and arms distinct.

Frons subtriangular, as wide as long, with four setae.

Labrum subtriangular, broader than long, four setae on dorsal surface.

Epipharynx bearing fourteen setae or sense cones of varying lengths. The surface is also densely covered with very small spines.

Ocelli wanting.

Antennae located at lateral angle of frons.

Mandibles stout, triangular, one dorsal setae, apex black.

Maxilla with cardo distinct and undivided, mala at apex obtuse, ventral surface smooth, dorsal surface with a longitudinal row of simple setae; maxillary palpus extending slightly beyond mala, two segmented, attached to a large membraneous palpifer visible from ventral aspect, basal segment with large dorsal setae.

Ligula bilobed, membraneous.

Labrum membraneous; labial palpa short, of two segments, with short terminal setae.

Mentum chitinous, with three prominent anterior projections and one posterior one.

Gula wider than long.

Thorax and abdomen with many prominent setae.

Spiracles lateral, with oval openings.

Color white, tips of mandibles black, setae brown.

Brachyrhinus sulcatus (Fab.)

Figures 2, 8, 14, 20, 25

An introduced species; the larvae feed on the roots of blackberries, cranberries, loganberries, primroses, raspberries, strawberries, and many other plants. Occurs in many parts of North America and is quite common in California, Oregon, Washington, and British Columbia.

LARVAE—

Mandibles with apex rounded.

Maxillary palpus with five to eight setae on distal end.

Mala with eleven setae on dorsal surface.

Mentum with middle projection as long as lateral.

Gula region broadly transverse.

Length of mature larvae 8 mm.

Specimens studied from Berkeley, Niles, and San José, California.

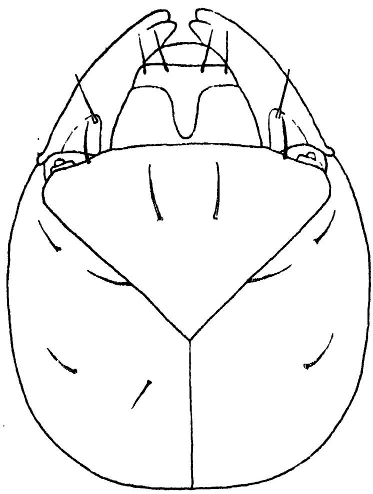

Fig. 3

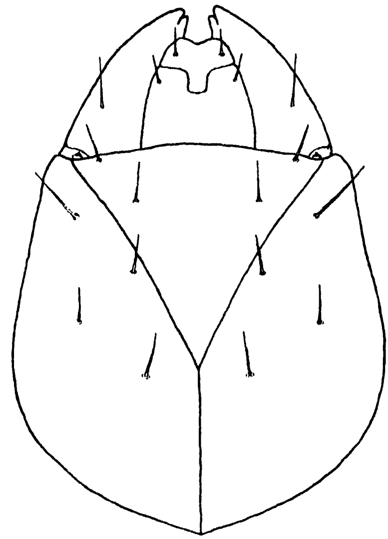

Fig. 4

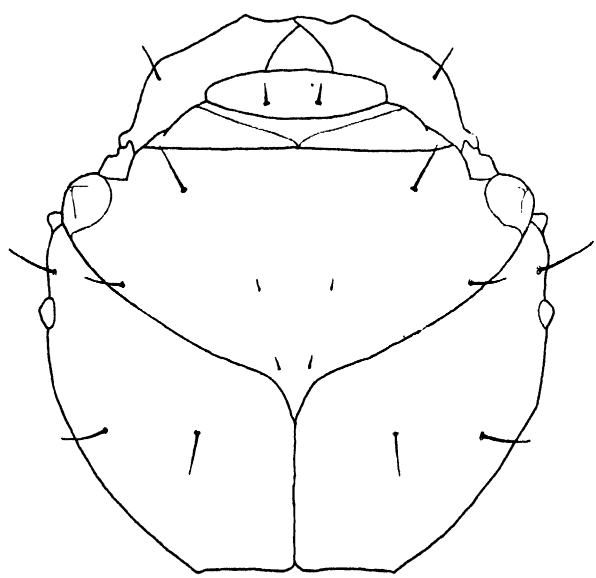

Fig. 5

Fig. 3. *Brachyrhinus ovatus* (Linn.), dorsal view of head of larva.
Fig. 4. *Brachyrhinus rugosotriatus* Goeze, dorsal view of head of larva.
Fig. 5. *Hypera punctata* (Fab.), dorsal view of head of larva.

PUPA—

Head exposed, flexed against the prosternum; mandibles parallel to body axis; dorsal surface with twelve recurved setae arising from tubercles.

Pronotum with median longitudinal impressed line; base slightly incised, basal angles broadly rounded; sides and apex arcuate; lateral margin with two setae; apex with four slightly recurved setae arising from prominent tubercles; lateral setae twice the size of median setae; central area with four setae, posterior pair very small.

Elytra with faint striae.

Legs prominent laterally, not appressed against the body, distinctly compressed and comparatively broad; tarsi indistinguishable; distal end of femur with two, unequal, and slightly recurved setae arising from tubercles.

Abdominal segments convex dorsally, less so ventrally; dorsal surface with longitudinal row of setae on each segment; setae on posterior segments more robust than setae on anterior segments; ventral surface without setae except last two segments; apex terminating in two, chitinous, brown tipped, spine-like processes.

Color of alcoholic specimens yellowish white, setae brown.

Length 8 mm.; width from knee to knee 5 to 5.5 mm.

Specimens studied from Berkeley and San José, California.

Pupation occurs in an earthen cell in the soil.

Brachyrhinus ovatus (Linn.)

Figures 3, 9, 15, 21, 26

An introduced species, very injurious in the larval stage, which feeds on the roots of strawberry, raspberry, and related plants. The adult is known to feed on the leaves and fruit of strawberry, raspberry, grape, apple, peach, and many other plants. It occurs in many parts of North America and is a serious pest of strawberries in British Columbia, Washington, and Oregon in the west. It has been recently found in Del Norte and Humboldt counties, California.

LARVAE—

Mandibles with bifid apex.

Maxillary palpus with five to eight setae on distal end.

Mala with eight setae on dorsal surface.

Mentum with middle projection as long as lateral.

Gula region triangular.

Length of mature larvae 6 mm.

Specimens studied from Woodburn, Oregon.

PUPA—

Head exposed, flexed against the prosternum; mandibles transverse to body axis; dorsal surface with twelve recurved setae arising from tubercles.

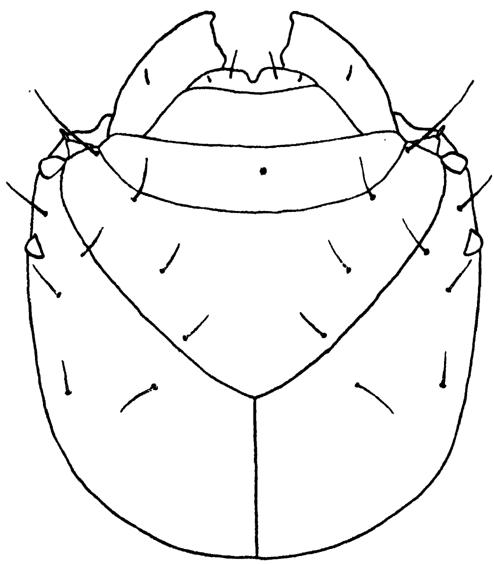

Fig. 6

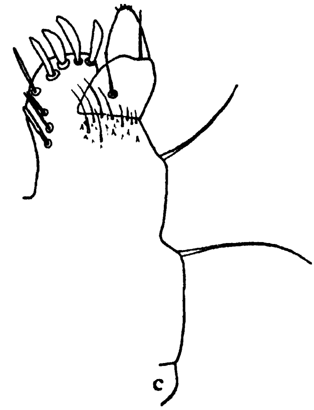

Fig. 7

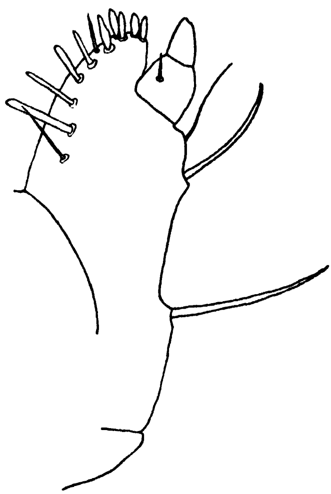

Fig. 8

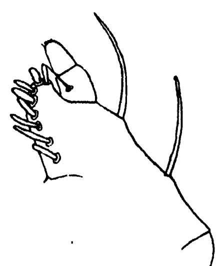

Fig. 9

Fig. 10

Fig. 11

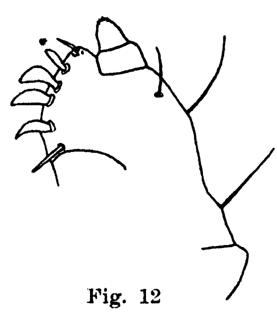

Fig. 12

Fig. 6. *Listroderes obliquus* Gyll., dorsal view of head of larva.
Fig. 7. *Pantomorus godmani* (Crotch), buccal side of mala: *c*, cardo.
Fig. 8. *Brachyrhinus sulcatus* (Fab.), buccal side of mala.
Fig. 9. *Brachyrhinus ovatus* (Linn.), buccal side of mala.
Fig. 10. *Brachyrhinus rugosostriatus* Goeze, buccal side of mala.
Fig. 11. *Hypera punctata* (Fab.), buccal side of mala.
Fig. 12. *Listroderes obliquus* Gyll., buccal side of mala.

Pronotum evenly convex; base truncate, basal angles broadly rounded; sides arcuate, with two setae; apex arcuate, with four recurved setae arising from tubercles; central area with two small setae.

Elytra[1] without any trace of striae.

Legs prominent laterally, not appressed against the body, distinctly compressed and comparatively broad; tarsi indistinguishable; distal end of femur with two, unequal, strongly recurved setae arising from tubercles.

Abdominal segments convex dorsally, less so ventrally; dorsal surface, except last two segments, with but few feeble setae, last two segments with longer and more robust setae; apex terminating in two, chitinous, brown tipped, spine-like processes.

Color of alcoholic specimens yellowish white, setae brown, appendages somewhat semitranslucent.

Length 7 mm.; width from knee to knee 3.5 mm.

Specimens studied from Woodburn, Oregon.

Pupation takes place in an earthen cell in the ground.

Brachyrhinus rugosostriatus Goeze

Figures 4, 10, 16, 22, 27

An introduced species, injurious in the larval stage to the roots of strawberries, blackberries, loganberries, and raspberries. In California it has been known for some time to occur in Humboldt and Del Norte counties, but has recently been taken in Santa Clara and Alameda counties.

Larvae—

Mandibles with apex bifid.

Maxillary palpus without setae at distal end.

Mala with eight setae on dorsal surface.

Mentum with middle projection longer than lateral.

Gula region broadly transverse.

Length of mature larvae 5 to 5.5 mm.

Specimens studied from Mt. Eden, California.

Pupa—

Head exposed, flexed against the prosternum; mandibles oblique to body axis; dorsal surface with ten recurved setae arising from tubercles.

Pronotum evenly convex; base slightly incised, basal angles rather acute; sides and apex arcuate; lateral margin with two small setae; apex with four recurved setae; central area with two setae.

Elytra with distinct striae.

[1] In a series of pupae from Woodburn, Oregon, all the elytra are transverse to the body axis; as this series was the only material that I was able to examine, I do not know whether this condition is due to the method of preservation or not.

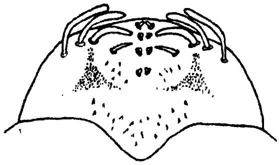

Fig. 13

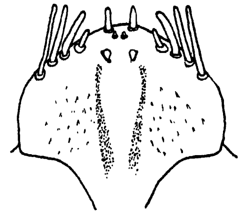

Fig. 14

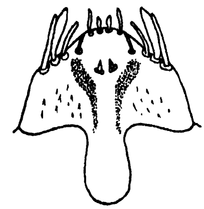

Fig. 15

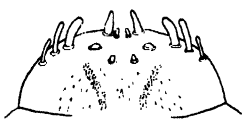

Fig. 16

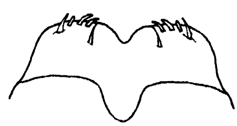

Fig. 17

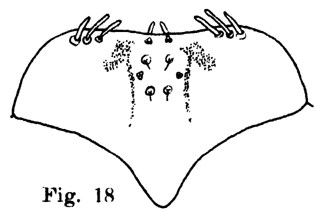

Fig. 18

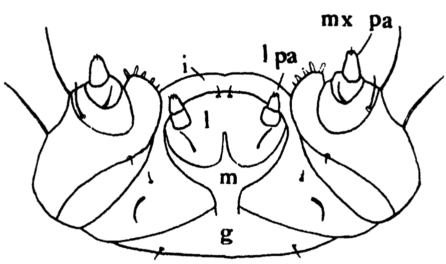

Fig. 19

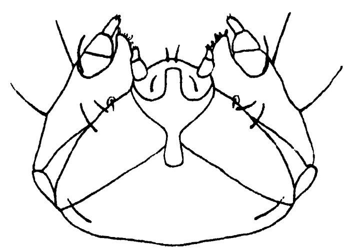

Fig. 21

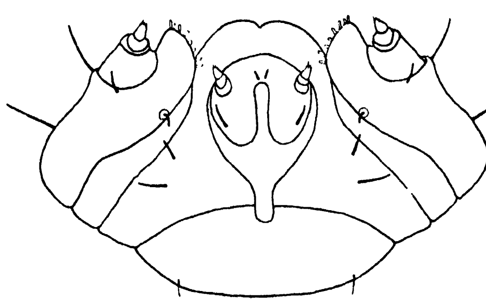

Fig. 20

Fig. 13. *Pantomorus godmani* (Crotch), epipharynx.
Fig. 14. *Brachyrhinus sulcatus* (Fab.), epipharynx.
Fig. 15. *Brachyrhinus ovatus* (Linn.), epipharynx.
Fig. 16. *Brachyrhinus rugosostriatus* Goeze, epipharynx.
Fig. 17. *Hypera punctata* (Fab.), epipharynx.
Fig. 18. *Listroderes obliquus* Gyll., epipharynx.
Fig. 19. *Pantomorus godmani* (Crotch), ventral view of mouth parts: *g*, gula; *i*, ligula; *l*, labrum; *l pa*, labial palpus; *m*, mentum; *mx pa*, maxillary palpus.
Fig. 20. *Brachyrhinus sulcatus* (Fab.), ventral view of mouth parts.
Fig. 21. *Brachyrhinus ovatus* (Linn.), ventral view of mouth parts.

Legs prominent laterally, not appressed against the body, distinctly compressed and comparatively broad; tarsi indistinguishable; distal end of femur with two, unequal, slightly recurved setae.

Abdominal segments convex dorsally, less so ventrally; dorsal surface with row of setae to each segment; setae on segments one to four very minute; last three segments with robust setae; apex terminating in two chitinous spine like processes.

Color of alcoholic specimens yellowish white, setae brown.

Length, 7 mm.; width from knee to knee, 3.5 to 4 mm.

Specimens studied from Mt. Eden, California.

Pupation takes place in an earthen cell in the soil.

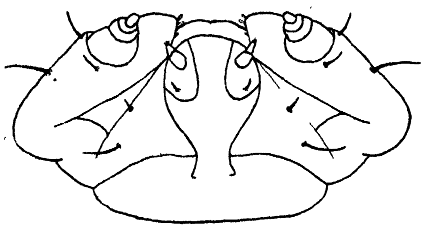

Fig. 22

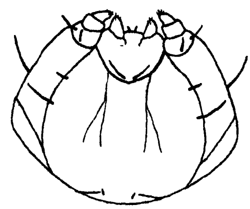

Fig. 23

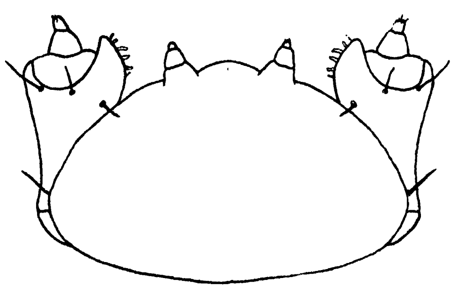

Fig. 24

Fig. 22. *Brachyrhinus rugosostriatus* Goeze, ventral view of mouth parts.
Fig. 23. *Hypera punctata* (Fab.), ventral view of mouth parts.
Fig. 24. *Listroderes obliquus* Gyll., ventral view of mouth parts.

Hypera punctata (Fab.)

Figures 6, 11, 17, 23

An introduced species, the larvae of which feed on the leaves of clover, alfalfa, beans, and related plants. It has been taken throughout the eastern states and on the Pacific coast from British Columbia to California.

LARVAE—

Head chitinized; yellowish brown, darker than rest of body; sides sub-parallel.

Epicranial stem and arms distinct.

Frons triangular; slightly wider than long; rather broadly arcuate at clypeal suture; provided with eight large setae.

Clypeus broadly transverse.

Labrum broader than long; bearing on dorsal surface two setae.

Epipharynx bearing ten setae or sense cones of varying lengths.

Ocelli (two) on lower part of each epicranial half, separated by three times their own diameter.

Antennae located at anterior margin of frons.

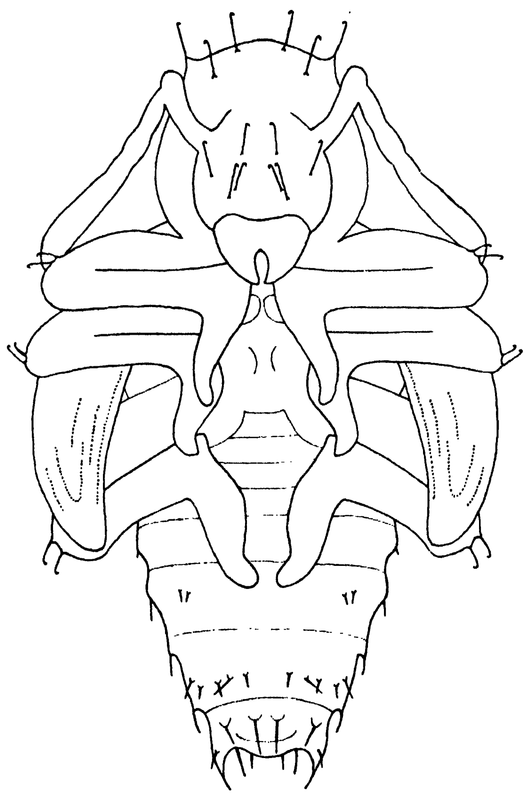

Fig. 25. *Brachyrhinus sulcatus* (Fab.), pupa.

Mandibles stout, triangular, single tooth at apex; dorsal surface bearing one setae; apex black.

Each epicranial half with five setae.

Maxilla with cardo distinct and simple; mala at apex obtuse, ventral surface smooth, dorsal surface with two rows of setae, inner row of six setae, outer row of three setae; maxillary palpi not extending beyond mala, two segmented, terminal segment with twelve to fourteen small terminal setae; palpifer bearing two large setae on ventral surface.

Ligula and labrum membraneous; labial palpus two-segmented, with small terminal setae.

Mentum represented by a narrow and rather heavily chitinized ring.

Gula small and poorly defined.

Thorax and abdomen with prominent setae; last abdominal segment small and ventral.

Spiracles lateral and with oval openings.

Color of alcoholic specimens yellowish white with darker head and brown setae. Tower and Fenton (1920) give a detailed account of the natural color for each instar.

Length of mature larvae 8 to 14 mm.

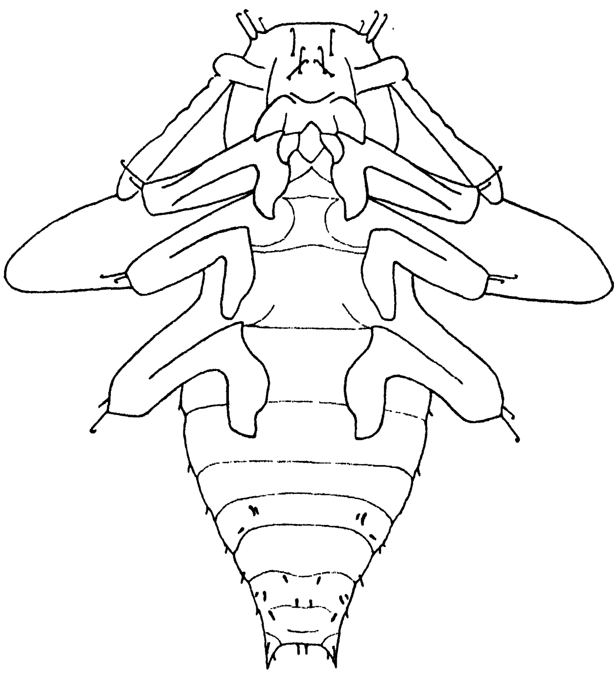

Fig. 26. *Brachyrhinus ovatus* (Linn.), pupa.

Specimens studied from Pullman, Washington; Forest Grove, Oregon; and Maryland.

The mature larvae form a cocoon of open meshwork in the soil or in the débris at the base of the plant.

Listroderes obliquus Gyll.

Figures 6, 12, 18, 24, 28

This destructive insect has been recently introduced into California, but it has been known for years in Louisiana and Mississippi. It is omnivorous in habit, but carrots, turnips, spinach, and tomatoes are especially favorite host plants. It feeds either above or below ground.

LARVAE—

Head chitinized; brown with spotted patches of black or dark brown; somewhat circular in outline, but distinctly truncate at base when seen from frontal aspect, a dorsal view of the larvae with the head extended shows a broad and shallow triangular incision at the junction of the two epicranial halves and the apex of the epicranial stem.

Epicranial stem and arms distinct.

Frons subtriangular, wider than long; provided with eight setae.

Clypeus broadly transverse, with triangular incision which the epistoma fills.

Labrum broader than long; two large setae on dorsal surface.

Epipharynx with twelve setae or sense cones.

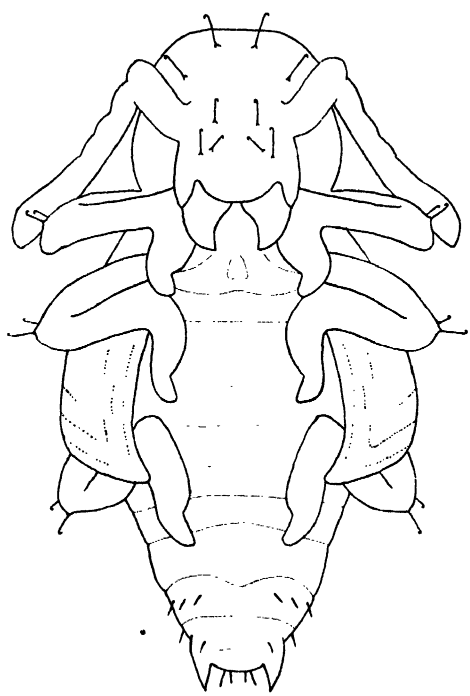

Fig. 27. *Brachyrhinus rugosostriatus* Goeze, pupa.

Each epicranial half with three setae on dorsal surface.

Two ocelli on lower part of each epicranial half.

Antennae at anterior margin of frons.

Mandibles stout, triangular, and bifid at apex.

Maxilla with cardo distinct and simple; mala at apex rather acute, ventral surface with four setae, dorsal surface with longitudinal row of six setae; maxillary palpus extended beyond mala, composed of two segments, terminal segment with small setae at tip, palpifer without setae.

Ligula, labrum, and mentum membraneous and fused together, labial palpa of two segments, as long as mixillary palpus.

Thorax without setae; dorsal surface convex; ventral surface less so; segments distinctly separated from one another by infoldings of the surface. Prothorax wider than long; tergal region with a dark brown, heavily chitinized, transverse band narrowly divided at the meson, the ends not reaching the spiracles and separated from them by the width of the chitinous band. Mesothorax and metathorax without chitinous dorsal plate, otherwise similar to prothorax.

Abdomen without setae; dorsal surface convex; ventral surface rather flattened; narrowed toward caudal extremity; tenth segment small and ventral.

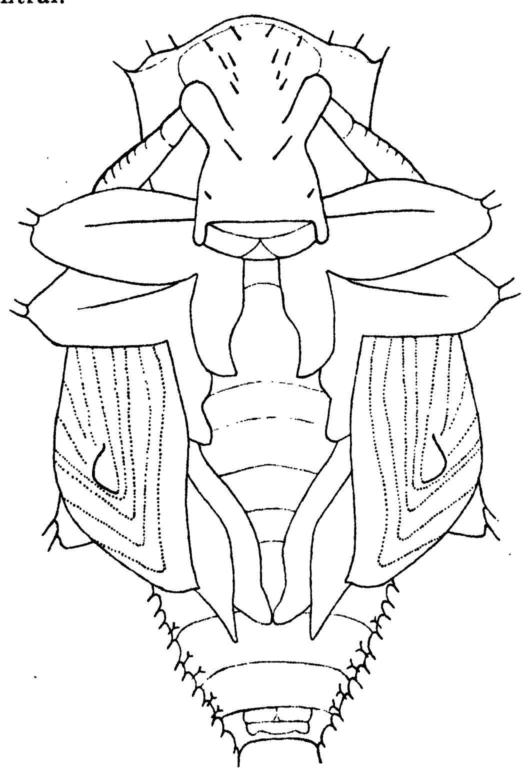

Fig. 28. *Listroderes obliquus* Gyll., pupa.

Spiracles lateral, with circular openings bordered by chitinous rings.

Color of alcoholic specimens yellowish white. The color of the living larvae on first hatching is yellowish white with a black head and prothoracic plate. The color gradually changes to a translucent pale green when the larvae is about one-third full grown and this is the normal color of the fully developed larvae.

Length of full-grown larvae 12 mm.

Specimens studied from Berkeley, San Francisco, and San José, California.

PUPA—

Head exposed, flexed against the prosternum; mandibles not visible from above; dorsal surface with sixteen short setae arising from small tubercles.

Pronotum evenly convex; base arcuate, with eight setae, basal angles rather acute; sides arcuate, with single setae; front truncate and without marginal setae; three pair of setae arranged over the central area.

Elytra with distinct striae; a prominent brown tipped tubercle on the center of each elytron.

Legs prominent laterally, not appressed against the body, distinctly compressed and comparatively broad; tarsi indistinguishable; distal end of femur with two unequal setae.

Abdominal segments convex dorsally, less so ventrally; dorsal surface with median longitudinal impressed line; each segment with transverse row of setae, apex terminating in two, brown, chitinous, spine-like processes.

Color of alcoholic specimens yellowish white, setae brown. McCarthy (1927) gives the color of the pupa as follows: "The head and thorax are light green, but the abdomen is slightly darker, and the rostrum, legs, antennae, and wing-pads are pale yellow."

Length 9 mm.; width from knee to knee 5 mm.

Specimens studied from Berkeley and San José, California.

BIBLIOGRAPHY

BEUTENMULLER, WM.

1891. Bibliographical catalogue of the described transformations of North American Coleoptera. Jour. New York Micros. Soc., 7:1–52.

BOVING, A. G., and CHAMPLAIN, A. B.

1920. Larvae of North American beetles of the family Cleridae. Proc. U. S. Nat. Mus., 57:575–649, pls. 42–53.

BUCHANAN, L. L.

1927. Synonymical notes on several Otiorhynchid weevils (Coleoptera). Can. Entom., 54:183–184.

COTTON, R. T.

1924. A contribution toward the classification of the weevil larvae of the subfamily Calendrinae occurring in North America. Proc. U. S. Nat. Mus., 66:1–11, pls. 1–10.

ESSIG, E. O.

1926. Insects of Western North America, pp. 491–496.

HAMILTON, C. C.

1925. Studies on the morphology, taxonomy and ecology of the larvae of holarctic tager-beetles (Family Cicindelidae). Proc. U. S. Nat. Mus., 65:1–85, pls. 1–12.

HAYES, W. P.

1928. The epipharynx of lamellicorn larvae (Colep) with a key to common genera. Ann. Entom. Soc. Am., 11:282–306, pls. 15–17.

HERRICK, G. W., and HADLEY, C. H., JR.

1922. The clover-leaf weevil. Cornell Univ. Agr. Exp. Station, Bulletin 411.

LARRIMER, W. H.

1926. The clover-leaf weevil and its control. U. S. Dept. of Agr., Farmer's Bulletin No. 1484.

MCCARTHY, T.

1927. Brown vegetable weevil. Dept. of Agr., N. S. W., Insect Pest Leaflets No. 13.

TOWER, D. G., and FENTON, F. A.

1920. Clover-leaf weevil. U. S. Dept. of Agr. Bulletin 922, pp. 1–18.

THE BIOLOGY OF CERTAIN COLEOPTERA ASSOCIATED WITH BARK BEETLES IN WESTERN YELLOW PINE

BY

GEORGE R. STRUBLE

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INTRODUCTION

The study of forest entomology in America has been limited almost entirely to the insects more important economically, chief among which are the bark and wood borers. There is, however, another field of investigations which has been much neglected—a study of the associated insect fauna. After bark and wood borers have successfully overcome the resistance of living trees, an environment is established which attracts numerous species of insects of secondary importance, represented chiefly by the orders of Coleoptera, Diptera, and Hymenoptera. The importance of many of these forms comes about through their effect on the primary insects, directly as predators and parasites, and indirectly as scavengers or phytophagous feeders, diverse rôles in which they affect the development of the primary

insects. Of these the order Coleoptera is represented by the greatest number of species and for this reason the writer has selected a few of the more important representatives of this order for this study.

The literature dealing with the biology of the Coleoptera found associated with bark beetles under the bark of dead or dying forest trees is very limited. Perris (1852) made one of the earliest contributions in his studies of the insects infesting the maritime pine, which covered a period of ten years, 1852–1862. Forest entomologists in Europe and America have observed the habits of a great many associated insects and have recorded them in the literature, but no comprehensive studies have been made in this country. The biology of associated Coleoptera in western yellow pine is still untouched except for a few species. Person (1928) in an unpublished report has worked out the life-history and habits of the clerid, *Enoclerus lecontei* Wolc., a very important predator of *Dendroctonus brevicomis* Lec., and of *Temnochila virescens* var. *chlorodia* Mann, another important general predator. But the biologies of the vast majority of associates are still unknown. This study was undertaken to fulfil a threefold purpose: first, to further the biological knowledge of the lesser known bark Coleoptera; second, to determine the importance of some associated Coleoptera in relation to bark beetle control; and finally, to secure a greater knowledge of the immature stages to be found under the bark. Four species have been studied, which are representatives of three families as follows: Histeridae, *Platysoma punctigerum* Lec. and *Plegaderus nitidus* Horn; Tenebrionidae, *Hypophloeus substriatus* Lec.; Staphylinidae, *Nudobius pugetanus* Csy.

Acknowledgments

The present study was commenced while the author was in the service of the United States Bureau of Entomology, Office of Forest Insect Investigations, F. C. Craighead in charge. Here I received considerable assistance from my associates, especially from Mr. H. L. Person, who was directly responsible for my beginning this study and who also aided me in the field work. Assistance was also received from Mr. J. M. Miller, who gave me many helpful suggestions, from Mr. N. T. Mirov who translated Gusev's (1928) article from the Russian, and from Mr. Albert Wagner, who was with me in the field. In addition, I am indebted to Dr. E. C. Van Dyke under whom the laboratory studies were made, for his many valuable suggestions and criticisms

of laboratory work, for the correction of manuscript, and for the loan of specimens; to Professor W. B. Herms for suggestions and for the loan of laboratory equipment, and to Professor E. O. Essig and Dr. S. F. Light for helpful suggestions. I am also very grateful to the Taxonomic Division of the United States Bureau of Entomology for revisions which were made in the descriptions of larvae and for the references to studies by Schiödte and by Saalas. These revisions have been enclosed in quotation marks.

METHODS

The life-history stages of the beetles included herein were taken in the yellow pine areas of Modoc County, California, during the summer seasons of 1928 and 1929. Most of the field studies were carried on in the North Warner Mountain district embracing an area ranging in elevation from 5000 to 6000 feet. Trips were frequently made to the western portion of the county to secure further data on life-histories.

Rearing experiments were conducted in the field laboratory of the United States Bureau of Entomology. These experiments were carried on in two ways: First, approximately 500 adult *Dendroctonus brevicomis* Lec. were introduced into each of two rearing cages, which contained fresh green logs. After the beetles had attacked the logs, approximately 100 of each species of secondary insects were placed in the cages with them, so that in each log there were 500 adult *Dendroctonus brevicomis* Lec. and 100 each of the associates. One cage was kept as a check and the other was used for study purposes, the developments being noted once each week. In the second type of experiment, rearing was conducted in glass jars in which were placed green blocks of wood with the bark attached. Fifty adult specimens of *Dendroctonus brevicomis* Lec. were placed in each of the jars used. When the wood was well infested, 50 specimens each of all the beetles studied were placed in the respective jars, so that, in each jar, there were 50 specimens of the bark beetles and 50 specimens of a single species of an associated insect. Weekly observations were made in order to study feeding habits and brood development. Feeding experiments were conducted in the laboratory by placing associates in vials with their supposed hosts.

Studies were also carried on under natural field conditions. For this purpose thirty trees were cut as follows during the 1929 season:

one tree killed during the summer of 1928, twenty trees killed during the autumn of 1928 (by overwintering *Dendroctonus brevicomis* Lec.), and nine trees killed during 1929. Studies were also made on trees cut during 1928 and data were secured as well on trees killed during 1927. Certain trees were selected by the writer for careful weekly observations of the insects in all stages of development and for the study of their feeding habits.

All morphological and taxonomic studies were conducted in the Entomological Laboratory of the University of California. Drawings were made with the aid of the camera lucida.

HISTERIDAE

The family Histeridae is a moderately large group of beetles with very hard integument. Most of them are small or medium-sized "having the elytra truncate behind leaving two segments of the abdomen exposed"[1] and nearly all are of a shining black color. All members are predaceous, so far as is known. They are found in the carcasses of dead animals, in excrements, in ants' nests, and under the bark of trees. The species discussed in this paper, *Platysoma punctigerum* Lec. and *Plegaderus nitidus* Horn, are found under the bark.

Platysoma punctigerum Lec.

The genus *Platysoma* was erected by Leach in 1817 and adopted by Erichson in 1834. De Marseul in his monograph (1853) described thirty species. Several species have been added since. Blatchley (1910) treated *Platysoma* as a subgenus of *Hister* belonging to the tribe Histrini. Gusev (1928) placed it under *Cylistoma*. At the present time, however, *Platysoma* is recognized by most workers as a distinct genus. It is treated under the subfamily Histrinae in Leng's catalog (1920). This is a very ancient genus as shown by Handlirsch (1921). He reports *Platysoma* from Baltic amber, the Miocene of Florissant, and the Quaternary of England.

Two of the members of this genus have been studied in detail. Perris worked out the biology of *Platysoma oblongum* Fab. in mari-

[1] Blatchley, p. 598.

time pine and permitted De Marseul (1853) to use his observations. To quote from De Marseul on the habits of the larva:

> Cette larve est exclusivement carnassière. En Mai, le *Platysoma* ♀ suit le *Tomicus stenographus,* qui perfore l'écorce au Pin, dépose ses oeufs dans les galieres et entre les oeufs de cellui-ci. La larve parasite qui en éclôt dévore ses hôtes, et au bout de cinq mois environ, ses évolutions achevées.

"The larva of *Platysoma compressum* Herbst is thoroughly described and figured by I. C. Schiödte in Naturhistorisk Tidsskrift, ser. 3, vol. 3, pp. 153–154, pl. 2, 1864." *Platysoma urvillei* Le Guill. is noted by Holdhaus (1927) to be very abundant under the bark and wood of several kinds of trees on the islands of Wallis, Vavao, and Tahiti.

"The imago of *Platysoma deplanatum* Gyll. is mentioned by Saalas (1917) as a typical insect under the bark of *Populus tremula, Betula* and *Pinus,* and the imago of *Cylistosoma* (=*Platysoma*) *angustatum* Hoffm. under bark of *Pinus silvestris, Picea excelsa* and also of *Quercus ruber.* In the same work Saalas treats the biology of *Cylistosoma* (=*Platysoma*) *lineare* Er., which he records from below the bark of pine and spruce and common in the galleries of Ipidae; he comments on the characters of its larva and pupa giving figures of the anatomical details of the larva and a drawing of the pupa."

Platysoma punctigerum Lec. was first described as Hister (*Platysoma*) *punctiger* by Leconte (1861) from material taken in California. This species is distributed throughout the yellow pine regions of Oregon, California, and Arizona. It occurs in moderately large numbers under the bark of trees recently killed by *Dendroctonus brevicomis* Lec. or other scolytid beetles, and is considered an important predator.

Description of Stages

Figures A and B

Eggs.—Length 1–1.40 mm., elongate; color pearly-white; one to three eggs maturing at a time.

Larva.—Mature length 8–9 mm.; head two-thirds as long as thorax, chitin much hardened, cranial suture forming a Y; "ocelli absent: each antenna three segmented, the terminal segment much smaller than the others and inserted on the inside of the top of the middle segment; on the outside is found a small tactile cone; clypeus and labrum are fused together and with frons forming a nasale which anteriorly projects into a pair of not entirely symmetrical, short, rectangular, lobe-like teeth that are separated by a shallow emargina-

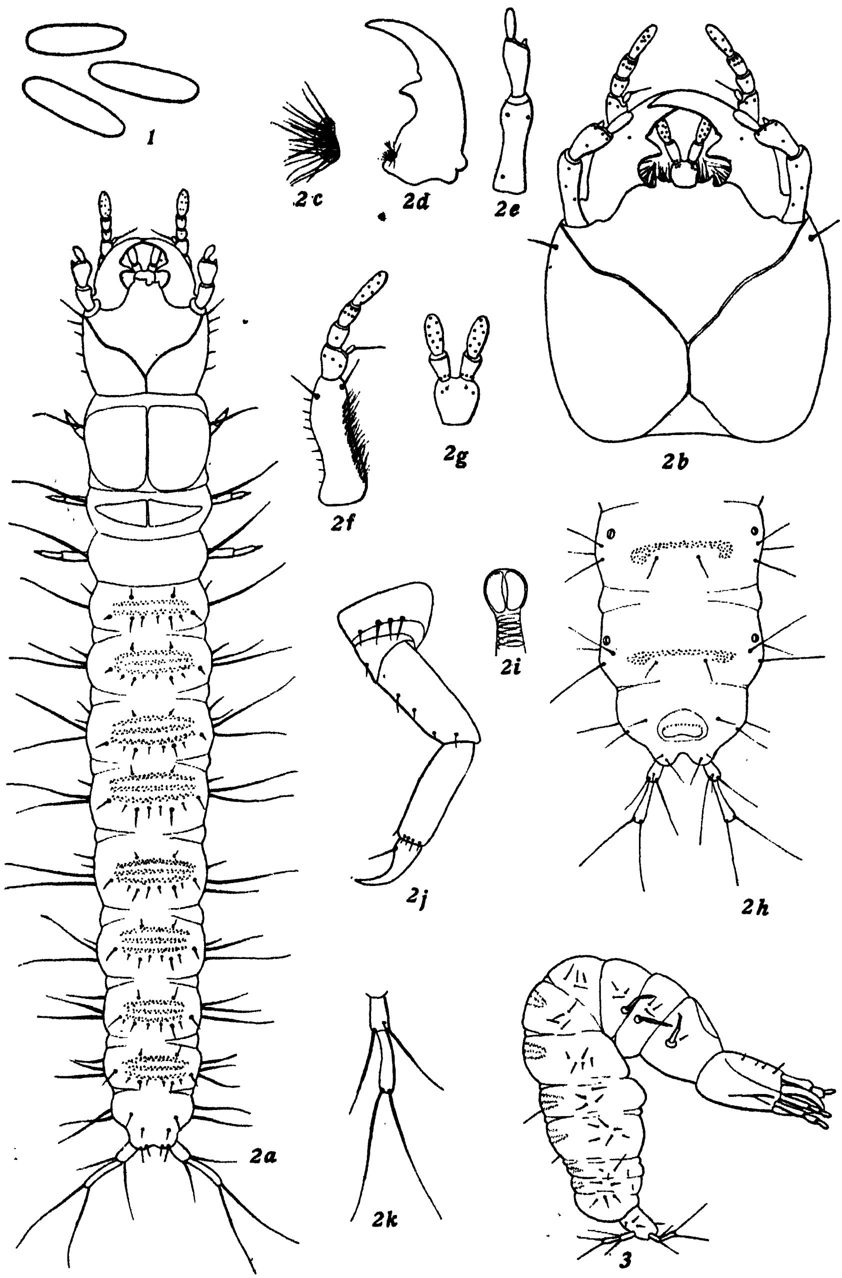

Fig. A. *Platysoma punctigerum* Lec.

1, eggs; 2*a*, larva (dorsal aspect); 2*b*, head of larva (dorsal); 2*c*, enlargement of hairs at base of mandible; 2*d*, mandible; 2*e*, antenna; 2*f*, maxilla; 2*g*, labium; 2*h*, posterior end of abdomen (ventral) showing cerci; 2*i*, spiracle; 2*j*, leg; 2*k*, cercus; 3, pre-pupal larva.

tion as wide as each tooth''; mandibles heavy containing two teeth on the inner surface, the lower very much larger than the upper one, and incurved; base of mandible with patch of hairs on inner surface; maxillae large with row of hairs on inner surface; maxillary palpi of four segments; ''three segments and palpiger developed as a basal joint carrying a papilla-like galea with a stout terminal bristle''; all segments containing scattered sensory pits; labium with two-segmented palpi, ''and no ligula.''

Prothorax as long as mesothorax and metathorax combined, chitin hardened, quadrate with sides nearly parallel, with dorsal median suture; mesothorax with chitin much hardened ''with a pair of heavily chitinized dorsal plates'' and containing a pair of spiracles on lateral ventral margin near junction with the prothorax; metathorax not so hard; legs ''inserted on the sides and widely apart, moderately long, five jointed ending with a tarsal joint that is strong, falciform, claw-like and carries a short bristle at base.''

''Abdomen consists of ten segments. Each of the first eight segments are dorsally armed with from two to four, usually three, rows of spines, ventrally with one row; each segment carries a pair of lateral spiracles. The ninth abdominal segment is almost as wide and considerably longer than the eighth abdominal segment, is without rows of spines and bears a pair of anal cerci, each cercus consisting of two segments, of which the terminal is more slender and twice as long as the proximal; both segments have two long, stout hairs. The tenth abdominal segment is developed as a short, subcylindrical, soft pygopod which bears the anal aperture in the center of the sucking surface. Spiracles bifore and sessile.''

Prepupal larva.—Head and thorax bent in toward abdomen; abdomen somewhat shortened, the last four segments drawn closely together; the ninth abdominal segment much distorted but still retaining the two-segmented cerci.

Pupa.—White, delicate, in cell hollowed out in frass; quadrate, head buried beneath pronotum, entire thorax with parallel sides; abdomen usually conical, the last segment with vestiges of anal cerci.

Adult.—Four to 5 mm. long, 1.5 to 2 mm. wide, quadrate, shining black; elytra covering first two abdominal and half of third abdominal segments, rarely covering first three entirely.

Head small, round, with transverse suture on vertex between compound eyes; another suture extending across front; capable of being extended or retracted from prothorax; chitin much hardened and with scattered pits. Antennae inserted in pit between mandibles and base of compound eyes; scape as long as funiculus and club combined, funiculus seven-segmented, club three-segmented, covered with numerous hairs. Mandibles heavy, with one tooth and a row of hairs on inner margin. Maxillary palpi four-segmented, with scattered pits; galea and lacinia with numerous hairs on inner surface. Labial palpi three-segmented with scattered pits; paraglossae not joined at base; fringed with tactile hairs on inner surface.

Pronotum quadrate with anterior end incurved to receive head when retracted, sides parallel; prosternum with rounded out-curved

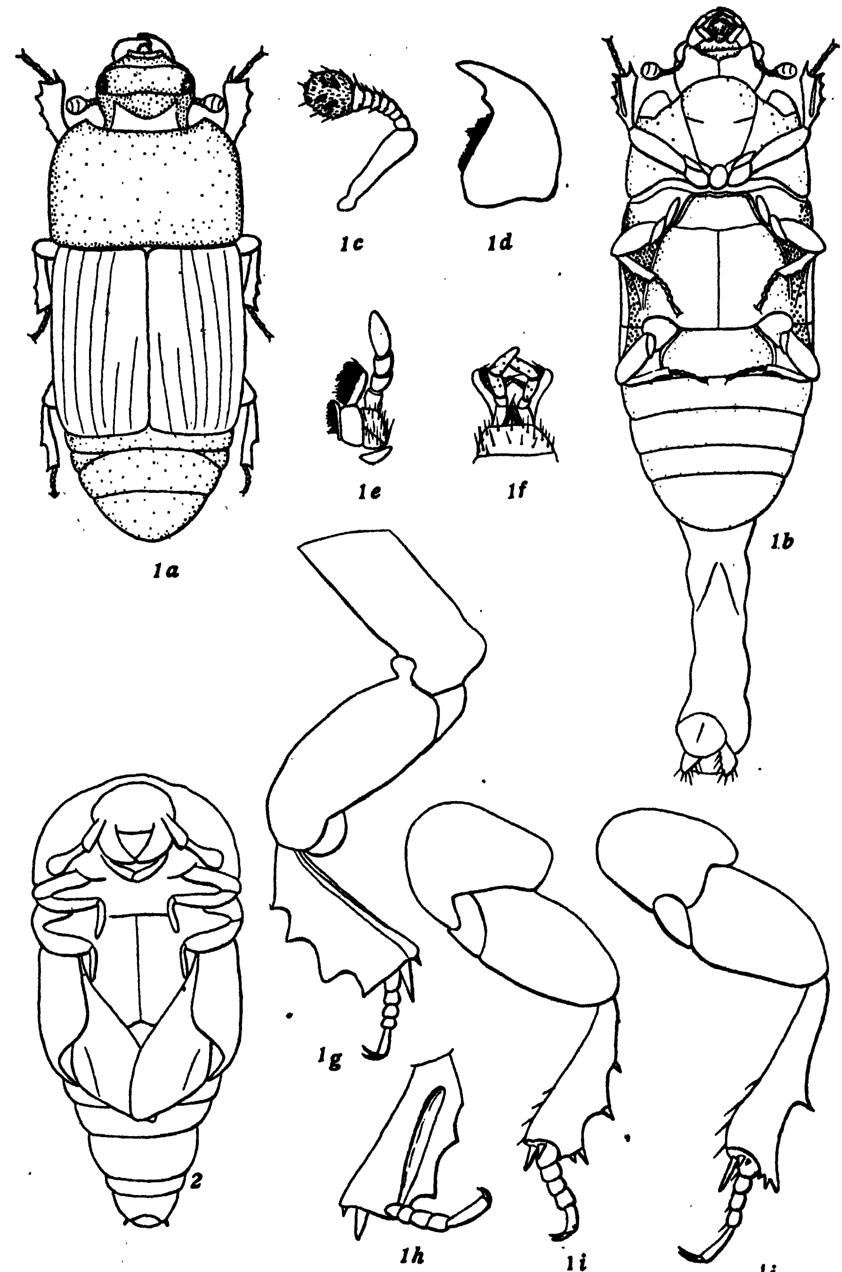

Fig. B. *Platysoma punctigerum* Lec.

1*a*, adult (dorsal aspect); 1*b*, adult (ventral aspect with ovipositor extended); 1*c*, antenna; 1*d*, mandible; 1*e*, maxilla; 1*f*, labium; 1*g*, fore leg; 1*h*, fore tibia (ventral aspect) showing groove; 1*i*, middle leg; 1*j*, hind leg; 2, pupa.

lobe extending anteriorly, separated from mesosternum by membrane; tibiae of fore legs broad, four-dentate on outer margin, containing groove on ventral surface, two striae on outer edge of dorsal surface, tarsi five-segmented, the terminal segment longer than the others and bearing the claw.

Mesosternum narrow with heavy sutures on lateral margins near junction of median pair of legs; tibiae of median legs not so broad as fore legs, outer margin three-dentate, tarsus, five-segmented as in fore legs; elytra shining black containing six longitudinal striae on each elytron, the inner two striae of each elytron shorter than the others.

Metasternum with longitudinal median suture joining transverse suture which extends laterally to grooves containing hind pair of legs; tibiae of hind legs two-dentate on outer margin, narrower and more slender than tibiae of the other two pairs of legs; tarsus five-segmented.

Abdomen of five segments. Ovipositor of female longer than abdomen, of five segments, mostly membranous, protruding from fifth or anal segment, and bearing two very rigid claspers.

Life-History and Habits

Platysoma punctigerum Lec. spends the winter under the bark only in the adult stage. The adults gain entrance by means of the ventilation holes[2] which are bored by bark beetles. They remain dormant in the bark beetle egg galleries until the approach of warm weather in spring when they again become active and search for food. By this time they have also become sexually mature, and the warmth stimulates them to mate and lay eggs. Egg-laying begins ordinarily in May and continues for a period extending over three to five weeks. The eggs are deposited along the sides of bark beetle egg galleries and sometimes in the frass material. They are laid ordinarily in small groups, the eggs rarely exceeding three in number.

Within ten days to two weeks, depending on the temperature conditions, the young larvae hatch out. They are voracious predators, actively running from one place to another in the bark beetle galleries in search of food, which normally consists of various small coleopterous and dipterous larvae. *Platysoma punctigerum* Lec. larvae have been observed by the writer to feed upon the larvae of *Nudobius pugetanus* Csy., *Othnius lugubris* Horn, and Diptera. They are also cannibalistic. The fact that *Dendroctonus brevicomis* Lec. larvae bore within the bark makes it impossible for *P. punctigerum* Lec. to prey upon them.

[2] Small holes bored to the outside at intervals along the egg galleries during construction.

The larval development of *P. punctigerum* Lec. is rapid; only four to six weeks are required at temperatures between 65 and 90° F. The time required for *Platysoma* to complete its larval development is but slightly longer than that required for the development of *D. brevicomis* Lec. either remain in the tree where they were reared or fly to a out an elliptical pupation chamber in the frass material of bark beetles. The chamber is about half the length of the larva and slightly wider. The larva rests with the head and thorax bent in against the abdomen. It loses the use of all appendages; any movement which it makes when disturbed is accomplished by rotating the abdomen. This prepupal stage endures only from two to four days, after which the pupa is formed. The pupal stage lasts from ten to fourteen days.

When the adult emerges it is a pale yellowish-red. The color of the body gradually intensifies, turning darker red, maroon, and finally shining black with reddish-brown legs. The changes in color are due to depositions of pigment. The adults of *Platysoma punctigerum* Lec, either remain in the tree where they were reared or fly to a tree which has been recently killed. They are predaceous feeders. Their prey is not limited to a single species, but consists of many of the larval and adult stages of insects to be found under the bark. The writer has observed them feeding on the following insects: *Dendroctonus brevicomis* Lec. adults, *Hypophloeus substriatus* Lec. adults, *Othnius lugubris* Horn larvae, *Graphisurus spectabilis* (Lec.) larvae, dipterous larvae, *Ips emarginatus* Lec. adults, and *Platysoma punctigerum* Lec. larvae and adults. They attack their prey by approaching it from the rear and usually when it is in a tightly confined space. The adult insects are attacked at a point where the tissue is not heavily chitinized, usually at the juncture of the head and prosternum. The size of insect is evidently not a limiting factor in food selection by this species as shown by the attack made on a fully grown *Graphisurus spectabilis* (Lec.) larva, which is twenty to thirty times the size of *Platysoma.*

The total period required to complete a life-cycle during the summer is from seven to nine weeks, depending largely on temperature conditions. In the Modoc region during 1929, mature eggs were dissected from females by the writer on the 24th of May. Eggs were seen from time to time in the field from June 14 until the first of July. Fully grown larvae were first noted July 6, prepupal larvae July 10, pupae July 12, and adults July 25. Fully grown larvae, pupae, and adults were commonly found August 1. Thus a genera-

tion which is begun the first of June or later is completed by July 25 or later.

The adult insects which are produced in the first summer generation enter trees which have been recently attacked by *Dendroctonus brevicomis* Lec. A small percentage of them remains in the tree where they were reared. A second brood appears between September 25 and October 15, the adults of which hibernate. Thus two complete generations are produced during the summer, the second overwintering.

Importance as a Beneficial Insect

Platysoma punctigerum Lec. is very definitely predaceous on *Dendroctonus brevicomis* Lec. adults and was at first thought to be of considerable value as a possible natural control. Later investigations showed that it entered the egg galleries of *D. brevicomis* Lec. from three weeks to a month after its host had made its attack and at that time egg-laying was very nearly completed. Thus this beetle would have very little effect on the developing broods except where the development was unusually slow. Some of the *D. brevicomis* Lec. "parent adults" that are preyed upon by *Platysoma punctigerum* Lec. would ordinarily bore out of the bark at the end of four or five weeks and infest other trees.[3] *P. punctigerum* Lec. in this respect may be of great value.

Plegaderus nitidus Horn

The genus *Plegaderus,* described by Erichson (1834), is represented by small species of insects which are found under the bark of trees. Leconte and Horn (1883) place this genus in the subtribe Saprini of the tribe Histrini. Leng (1920) treats it as a genus of the subfamily Histrinae in which he is followed by most later systematists though Handlirsch (1923) places it in the tribe Abraeini Seidl. The members of this genus are

> small oblong species having a broad prosternum with a deep channel on each side extending from the lobe to the tip, and also a broad transverse groove which divides the median convex portion of the prosternum into two unequal portions. The thorax has a deep groove on each side and also, usually, a transverse impression which divides it into two unequal parts.[4]

[3] The habit of *Dendroctonus brevicomis* Lec. in this respect has been noted by field men of the Bureau of Entomology, and may be of great importance. Studies on this habit of other species of bark beetles have been published by Orest, Marcu (1926), and Simpson, L. J. (1929).

[4] Blatchley, Coleoptera of Indiana, p. 624.

Very little is known about the biology of any of the members of this genus. Packard (1890) quotes Perris on the larval habits of *Plegaderus discisus* Er.: "The larvae or grubs of *Plegaderus discisus* destroy the young of *Crypturgus pusillus.*" Jacquelin du Val (1857) quotes this habit from Perris and it is also noted by Nüsslin (1913). "Saalas (1917) records that the species *Plegaderus saucius* lives in the galleries of *Myelophilus piniperda* in spruce and *Ips typographicus* in pine, thus being of great economic importance as an enemy of some of the most injurious barkbeetles; he furthermore comments on the systematic characters of the larva and figures its ninth abdominal segment. The author also treats the different stages of the species *Plegaderus vulneratus* giving much biological information about its prey, life cycle, hibernating habits, occurrence, etc., and furnishes an elaborate, almost four pages long, description of the mature larva illustrated with a habitus figure and six drawings of anatomical details." Sixteen species occur in the United States, five of which are found in California.[5]

Plegaderus nitidus was described by Dr. G. H. Horn (1870) from a specimen which was taken in Nevada. This species is commonly found under the bark of yellow pine infested with bark beetles. It is distributed throughout the yellow pine regions of Nevada, California, and Oregon and is easily distinguished from other insects of yellow pine by its small size and shining black color.

Description of Stages

Figure C

Eggs[6].—Very small, white; length about .1 mm.; acorn-shaped, having a cap-like structure at the broad end.

Larva.—Length when mature about 4 mm.; color of head and prothorax light brown, balance of body white to cream; general appearance the same as the larva of *Platysoma punctigerum* Lec., except for size and a few other characters as follows: "Head more elongate; nasale less projecting, with three large teeth, of which the median tooth is quadrangular and anteriorly straight; antenna terminally with two small tactile cones seated in the oblique top of the middle segment; mandible falciform, on the inner margin with only one strong tooth which is placed slightly behind the middle; maxillary palpus four segmented, palpiger with the papilliform galea developed as a basal segment of the palpus; each labial palpus is inserted on a

[5] Leng, pp. 137–138.

[6] Eggs were obtained only by dissection of gravid females.

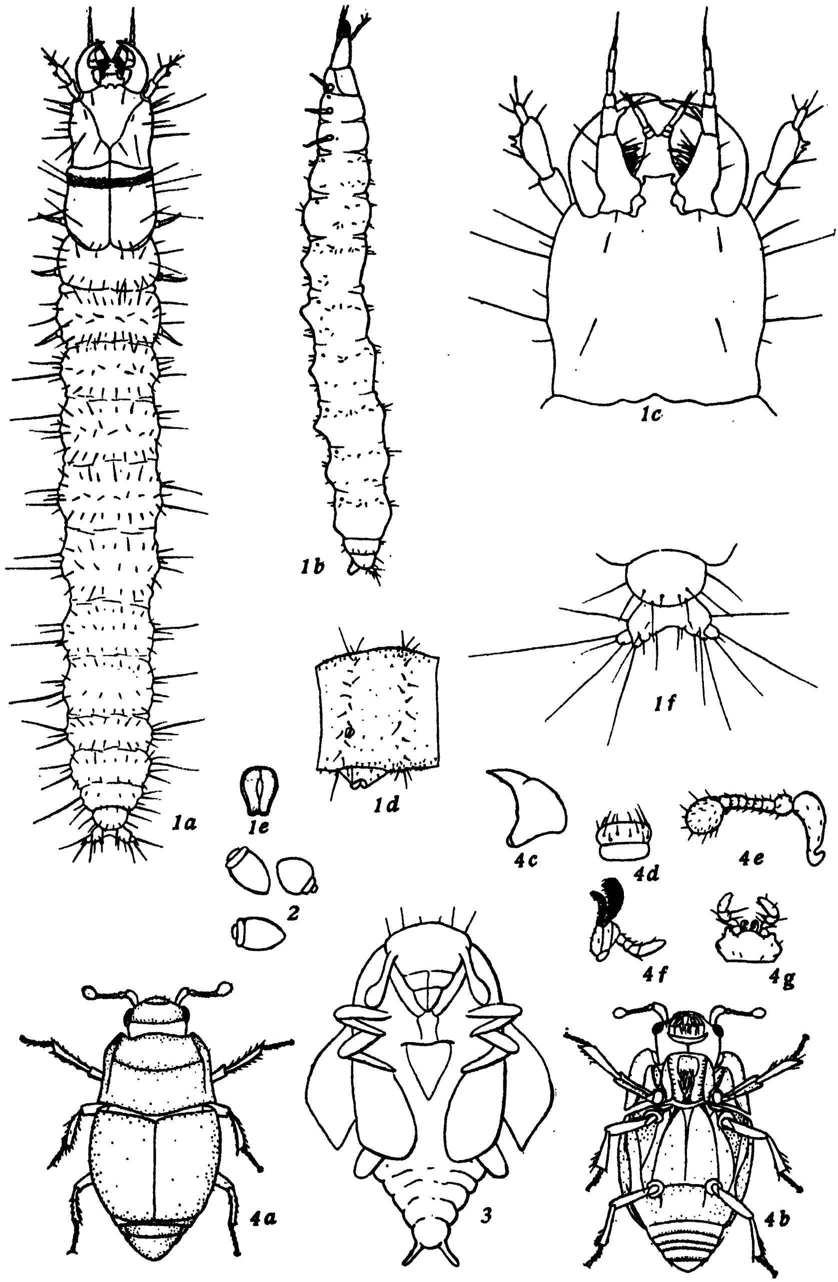

Fig. C. *Plegaderus nitidus* Horn

1*a*, larva (dorsal aspect); 1*b*, larva (lateral aspect); 1*c*, head of larva (ventral); 1*d*, lateral aspect of an abdominal segment showing spiracle and pseudopod; 1*e*, spiracle; 1*f*, pygidium and anal cerci; 2, eggs; 3, pupa; 4*a*, dorsal aspect of adult; 4*b*, ventral aspect of adult; 4*c*, mandible; 4*d*, labrum; 4*e*, antenna; 4*f*, maxilla; 4*g*, labium.

socle-shaped projection from prementum and is three-segmented with the proximal segment short, the median four times as long as the proximal and the distal segment slender, somewhat less than half as long as the median and is terminally beset with a few hairs. Mesothorax without a pair of thick dorsal shields; both meso- and metathorax with a dorsal arrangement of setae very similar to that of the abdominal segments; each leg about as long as the antenna, tarsal segment clawlike, straighter than in *P. punctigerum*. Most of the abdominal segments carry on the dorsal side a single transverse median row of hairs and besides this a somewhat denser row both along the anterior and the posterior margins of the segment. Ninth abdominal segment much shorter and narrower than the preceding and its sides strongly converging posteriorly; cerci diverging, obtuse, conical and short, about one and a half times as long as wide, indistinctly two-segmented with proximal segment much larger than the terminal; both segments with several stout bristles."

Pupa.—White, small, delicate, in frass material under bark, no special cells constructed; head drawn in against prosternum; length 2 mm., width 1 mm.; thorax somewhat quadrate; abdomen conical, with vestiges of anal cerci on terminal segment.

Adult.—"Oblong, moderately convex, black, shining. Antennae piceous, club paler. Head punctured. Thorax broader than long, narrower in front, sides at middle slightly sinuate, disc divided by a transverse sulcus into two unequal portions, sparsely and rather finely punctured than the posterior and more densely and coarsely near the lateral groove. Margin rather coarsely punctured and more densely in front. Lateral groove not attaining the basai margin. Elytra sparsely punctured but more densely and coarsely than the thorax. Prosternum bicanaliculate, median convex portion broadly interrupted and with a patch of silken hairs. Meso and metasternum very finely and sparsely punctured, side pieces and first abdominal segment coarsely punctured. Legs piceous, anterior tibiae gradually broader and finely denticulate. Length (from apex of thorax to tip of elytral suture) .09 inch; 2.25 mm."[7]

LIFE-HISTORY AND HABITS

The life-history of *Plegaderus nitidus* Horn is still somewhat obscure, but certain facts are presented here which will give a good conception of the development. The adults enter the bark through the ventilation holes made by bark beetles, just as does *Platysoma punctigerum* Lec. In the overwintering stages are found both adults and larvae. Both remain dormant until the approach of warm weather, when they again become active.

[7] Original description of adult by G. H. Horn (1870).

Eggs[8] are laid by the overwintering adults probably during the latter part of May and in June in the Modoc region. The larval development is slow; from eight to ten weeks are required to reach maturity. Pupation takes place in September and the adults emerge during the latter part of September and in October, to overwinter under the bark.

The larvae which overwinter develop to adults by the middle of July. This brood of adults enters trees which have been recently attacked by the western pine beetle. Eggs are laid presumably in the frass material of the bark beetles. The generation of larvae which follows has developed to half-grown larvae by the time cold weather comes on. Hibernation then takes place and as a result there is no further development until the following spring.

The feeding habits of *Plegaderus nitidus* Horn have not been so thoroughly studied as those of *Platysoma punctigerum Lec.* *P. nitidus* Horn have been observed to be predaceous both in the larval and adult stages. The larvae feed upon very small coleopterous and dipterous larvae under the bark. The adults have been noted to feed upon the eggs of *Dendroctonus brevicomis* Lec. and *Aulonium longum* Lec. In an experiment conducted by the writer, fifty eggs of *Dendroctonus brevicomis* Lec., together with two *Aulonium longum* Lec. eggs, were placed in a petri dish, with several *Plegaderus nitidus* Horn adults. After a period of twenty-four hours the eggs had all been devoured. Repetitions of similar experiments gave the same results. Under field conditions adult *Plegaderus nitidus* Horn were noted in *Dendroctonus brevicomis* Lec. egg galleries two weeks after a successful attack had been made. The fact of their presence at this time, when *D. brevicomis* Lec. eggs are still in the egg nitches, is good evidence that *P. nitidus* Horn may feed upon them.

As an insect of economic importance *Plegaderus nitidus* Horn may prove to be valuable in relation to natural bark beetle control. As an egg feeder it has possibilities for reducing the brood of *Dendroctonus brevicomis* Lec. Further studies are necessary, however, in order to determine its importance.

[8] Eggs were not actually found in the field, but were dissected from gravid females during the latter part of May and in June.

TENEBRIONIDAE

The family Tenebrionidae is a very large group of heteromerous beetles which are mostly dark colored, and which vary considerably in size and shape. The antennae are "usually bead-like or moniliform, the mouth parts rather small and not prominent."[9] According to Sharp (1899) and Blatchley (1910) about 10,000 species are known. The number of known species at the present time is probably somewhat larger. They are found on the ground beneath stones and damp logs, or about dead trees, chiefly under the bark. Many of them are closely associated with fungi. They are most abundant in semi-arid regions. One of the bark species, *Hypophloeus substriatus* Lec. is taken up in this study.

Hypophloeus substriatus Lec.

The genus *Hypophloeus* Fab. was placed in the tribe Diaperini by Horn (1870) and is considered to belong in the same tribe by Blatchley (1910). Kuhnt (1913) placed this genus under the tribe Ulomini and Leng (1920) treated it under the subfamily Ulomoninae. This genus is composed of small-sized beetles which are found under the bark of dead or dying trees, and which are more or less closely associated with fungi. "Gebien in Junk's Coleopterorum Catalogus (1910–1911) lists 47 species known to the world." Three species were listed for America north of Mexico by Horn (1870), but six more have been listed by Leng (1920), making a total of nine species at the present time. Two of these species are found in California, *Hypophloeus substriatus* Lec., and *H. opaculus* Lec. At least three undescribed species, one from California, are also represented in California collections.

The habits of *Hypophloeus* have been recorded by various authors. Perris (1852) first recorded the habits of *Hypophloeus linearis* Fab. According to him, *H. linearis* Fab. enters the galleries of *Tomicus bidens* through the same hole which the female *Tomicus* has bored, and there lays its eggs; and then the young *Hypophloeus* larvae, as soon as they hatch, should engage in a battle so serious that sometimes not one of the *Tomicus* larvae escapes. The habits of *Hypophloeus linearis* Fab. Perris believed to be new to science, and he considered

[9] Blatchley, *op. cit.*, p. 1243.

erroneus the common belief that the insect was lignivorous. Very emphatically he concludes as follows: "The larvae of *H. linearis* Fab. and *H. pini* Panz., which live in pine, and those of *H. castaneus* and *H. bicolor,* which inhabit the oak, are carnivores, or better to characterize their manner of living, larvivores."[10] Lacordaire (1859) indicates the wood feeding habits of *Hypophloeus.* Stebbing (1914) notes the "swarming habits" of *H. flavipennis* Mots. found in the galleries of *Polygraphus, Tomicus,* and *Pityogenes* infesting blue pine, spruce, and deodar in the northwest Himalaya Mountains, and is of the opinion that the larvae are predaceous or semipredaceous. Escherich (1923) notes the habits of *Hypophloeus* as taken from Kleine (1908–9), *H. fraxini* Kugel, *H. pini* Panz., *H. linearis* Fab., *H. fasciatus* Fab., *H. castaneous* Fab., and *H. bicolor* (Eich.), all of which are cited as enemies of various bark beetles. Gusev (1928) notes the habits of *H. longulus* Gyll. (*corticeus* Pill.) adults of which devour bark beetle eggs only, and the larvae of which feed on the bark beetle larvae. He also notes this habit for *H. fraxini* Kugel. He states that *H. linearis* Fab. feeds on bark beetle larvae in both the larval and adult stages. In North America the predaceous habits of *Hypophloeus* are indicated by Hopkins (1893) and Packard (1890).

Hypophloeus substriatus Lec. is the common species of the mountains of Oregon and California. It has been confused with *H. parallelus* Melsh., which is an eastern form extending only as far west as Arizona and the Rockies. All references to *H. parallelus* Melsh. found in the mountains of Oregon and California are therefore incorrect. Although the two species of *Hypophloeus* are very much alike in general appearance, there are certain specific characters which separate them.

H. substriatus Lec. is larger, being more elongate (average about 4.5 mm.) and broader. *H. parallelus* Melsh. averages about 3.5 mm. in length. Both have in general the same shape, but *H. parallelus* has its sides somewhat more parallel. *H. substriatus* Lec. is more tapering. The prothorax is longer in proportion to width in *H. parallelus* Melsh.; more truncate in *H. substriatus* Lec. The margin of the prothorax is conspicuously wider on *H. substriatus* Lec. Van Dyke points out a very good distinguishing character which is constant for each species, namely, punctulation. The propleurae of *H. parallelus* Melsh. are very closely and heavily punctulate. In *H. substriatus* Lec. the

10 Perris, p. 500.

propleurae are less clearly punctulate, thus giving a more shining appearance. The punctulation of the elytra of *H. substriatus* is arranged in rows, and is more scattered in *H. parallelus* Melsh.

Hypophloeus substriatus Lec. was first described by Leconte (1878) from specimens collected in Oregon by Lord Walsingham. It is commonly found under the bark of western yellow pine in association with bark beetles in Oregon and California.

DESCRIPTION OF STAGES

Figures D and E

Eggs.—White, elongate, with sides somewhat irregular; length .75 to 1 mm.

Larva.—Length when mature 5–7 mm.; head and thorax about one-third of total length; color yellowish to dark brown depending on degree of hardening of chitin, becoming darker toward posterior end of abdomen; "body rather short, with parallel sides, dorsally well chitinized and flatly convex, sparsely beset with hairs, ventrally rather softskinned. Head twice as wide as long, dorsally convex; frontal sutures distinct, median epicranial suture short, on each side with two, closely adjoining, almost fused ocelli; antenna three-segmented with a large basal membrane; proximal segment about as long as wide, median segment subclavate, almost three times as long as the proximal, distal segment minute, not longer than wide, carrying a few setae; tactile appendix absent; frons large, subcordiform; clypeus large, with the posterior half well chitinized and the anterior membranous; labrum distinct with semicircular outline, narrower than, but almost as long as, clypeus. Mandibles symmetrical, strong, exteriorly simply rounded without projecting tubercle; distal end of each mandible feebly bidentate; interiorly with a longitudinally excavated cutting part whose upper and lower margins carry a small tooth in the middle; molar part with rounded, slightly concave crown. Ventral mouthparts retracted; maxillary palpus three segmented, labial palpus two segmented; ligula distinct. Hypopharynx proximally with a transverse subrectangular chitinization and distally with a rather large softskinned part. Prothorax dorsally with a well developed shield; meso- and metathorax of the same size, each shorter than prothorax but together somewhat longer. Legs all of about the same length and shape; five segmented; clawshaped tarsus one-third as long as tibia. Abdominal segments number one to eight, all broader than long; ninth abdominal segment semicircular with the lateral outline continuous with that of the eighth segment, posteriorly rounded without cerci; tenth abdominal segment developed as a soft pygopod with a pair of short, conical ambulatory warts. Spiracles small, circular; nine pairs present, all lateral."

Pupa.—White, 3–4 mm. long; head covered by pronotum; pronotum sparsely covered by fine hairs; abdomen of seven segments dorsally and five ventrally; lateral margin of each ventral abdominal

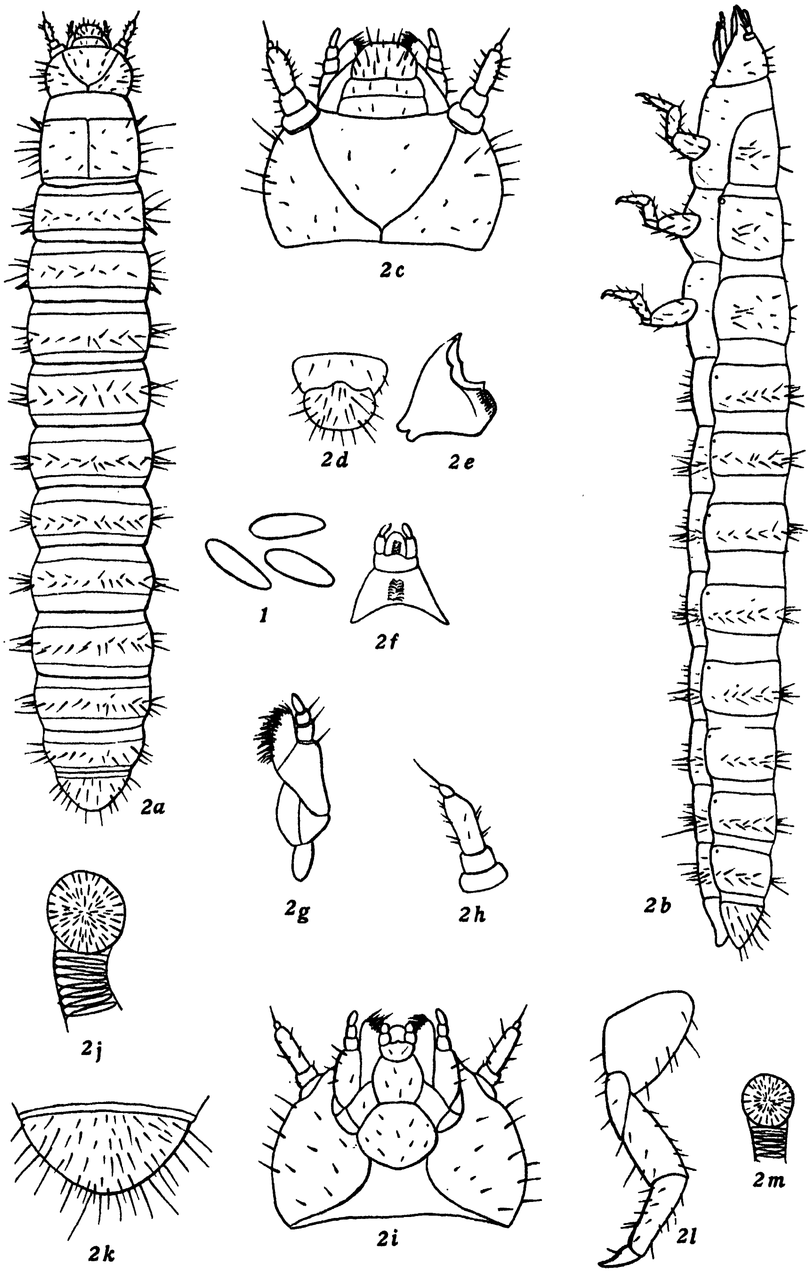

Fig. D. *Hypophloeus substriatus* Lec.

1, eggs; *2a*, larva (dorsal aspect); *2b*, larva (lateral aspect); *2c*, head (dorsal); *2d*, labrum; *2e*, mandible; *2f*, labium; *2g*, maxilla; *2h*, antenna; *2i*, ventral aspect of head; *2j*, thoracic spiracle; *2k*, pygidium; *2l*, leg; *2m*, abdominal spiracle.

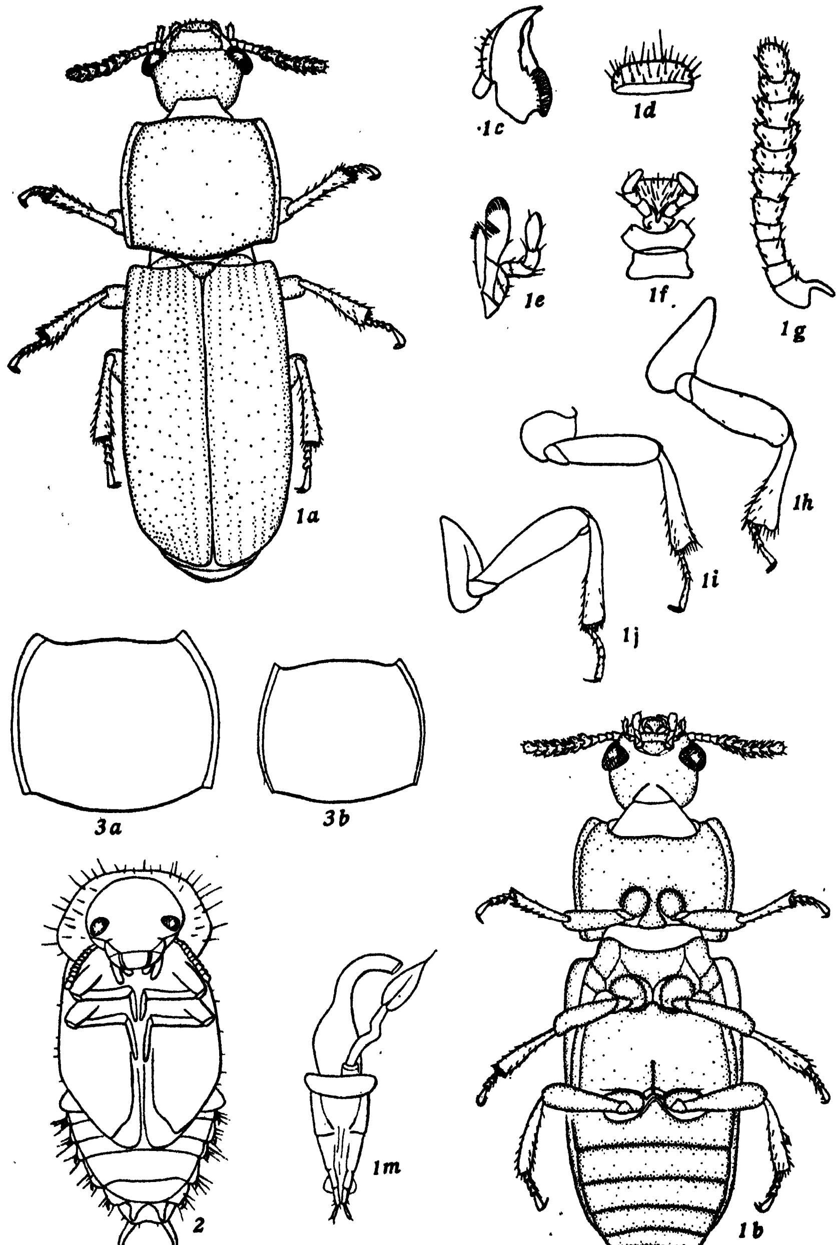

Fig. E. *Hypophloeus substriatus* Lec.

1*a*, dorsal aspect of adult; 1*b*, ventral aspect of adult; 1*c*, mandible; 1*d*, labrum; 1*e*, maxilla; 1*f*, labium; 1*g*, antenna; 1*h*, fore leg; 1*i*, middle leg; 1*j*, hind leg; 1*m*, ovipositor; 2, pupa; 3*a*, pronotum of *H. substriatus* Lec.; 3*b*, pronotum of *H. parallelus* Melsh.

segment with one in-curved spine; anal cerci present, having reappeared in this stage, but lacking in the larvae.

Adult.—General body color reddish-brown, somewhat shining; legs light brown, heteromerous; length variable, average 3–5 mm.; head small, somewhat quadrate; sparsely punctulate; compound eyes black; antennae eleven segmented, the basal four segments narrow, closely appressed, the six following segments broader, terminal segment rounded, all segments covered by fine hairs, the antennae inserted in groove between base of mandibles and compound eyes, maxillary palpi of four segments; labial palpi of three segments; mandibles with two terminal denticles with smaller denticles on inner margin, also molar surface; gular sutures converge but not joined anteriorly, gula not punctulate; fronto-clypeal suture across front between eyes dorsally; mandibles covered by labrum.

Prothorax broader than long; pronotum moderately convex, sides slightly arcuate laterally with narrow lateral margins, sparsely punctulate; prosternum moderately convex, sparsely punctulate; intercoxal piece lobed behind coxae; episternum and epimeron of mesothorax well defined; suture of epimeron joining metasternal suture a short distance from mesosternal coxae; elytra punctulate in longitudinal rows; inter-coxal piece not extending beyond coxae; metasternum broad; a median suture extending longitudinally from intercoxal piece one-third to one-half the distance to mesothorax; antecoxal piece divided.

Abdomen seven-segmented dorsally, five-segmented ventrally, dorsal portion covered by elytra (all covered except one-half of sixth and of seventh segments) with chitin rather soft; ventral segments very hard, sparsely punctulate; last abdominal segment with anal opening.

Life-History and Habits

Adults and larvae represent the overwintering stages of *Hypophloeus substriatus* Lec. The adults enter the bark of dead or dying yellow pines by means of the ventilation holes bored by bark beetles. The larvae which are not able to complete their development before the advent of cold weather remain under the bark, dormant until incited to activity by increased temperatures in spring. The largest proportion of the overwintering brood is in the adult stage. When the weather is warm enough, the adults again become active, mate, and lay eggs. The eggs are laid in small groups in the frass material and on the sides of the bark beetle egg galleries. The larvae hatch out within a week to ten days and actively run about in search of food material, which consists wholly of fungi under the bark. The larvae develop to maturity within eight to ten weeks. Pupation takes place in the frass material and no cells are constructed. The adults emerge within ten days to two weeks following pupation. They are at first

white, turning darker until finally they are a reddish-brown color. The summer brood which is started by overwintering adults is begun in June and is completed in September with the time of each stage as follows: eggs, ten days; larvae, eight to ten weeks; pupae, ten days to two weeks. The adults which emerge in September either remain under the bark where they were reared or fly to other trees which have been recently attacked by bark beetles. They remain under the bark to pass the winter.

The overwintering brood of larvae develops to maturity by the middle of July or the first of August. The adults which emerge, enter the summer brood trees of *Dendroctonus brevicomis* Lec. and lay eggs. These hatch into young larvae which are half or two-thirds grown before they are forced to hibernate. Thus a single generation is produced each year with an overlapping of stages so that adults and larvae are found during the winter and all stages are found during the summer.

It has already been pointed out that it is the belief (as expressed in most published works) that many of the species of *Hypophloeus* are predaceous insects, feeding on the eggs and larvae of bark beetles. I have not found this to be the case. *Hypophloeus substriatus* Lec., adults as well as larvae, are phytophagous, feeding on fungi under the bark. The larvae begin to feed very shortly after they hatch out of the egg stage. They have been reared to maturity by the writer on a pure culture of bluestain fungus grown on sterile phloem material, and have been observed to feed on bluestain fungi, blue green fungi, a white fungus, and fermented phloem under natural field conditions. Larvae after a short period of feeding become the same color as their food material. This is due to the contents of the alimentary canal which are visible through the body wall. The adults are also phytophagous and feed upon the fungus material found under the bark. Experiments which were conducted by the writer to determine whether this insect was also predaceous gave negative results. In no case could either the adults or larvae be forced to feed on either living or dead insects. *Hypophloeus substriatus* Lec. is therefore probably of little importance either as a beneficial or injurious species, except as it makes conditions more or less favorable for the development of associated insects, as, for example, through the spread of, or reduction in, the mycelium of fungi.

STAPHYLINIDAE

The family Staphylinidae is one of the largest groups of beetles. The species are easily recognized by the short, truncate elytra which cover only a portion of the abdomen, leaving several of the corneous segments exposed. The total number of species is not known definitely, but according to Sharp (1899) and Blatchley (1910) there are about 9000 species. The habits of the group are variable though most of them are either predaceous or scavengers. Some of them breed in manure heaps, in decaying vegetable matter, and in the bodies of dead animals. Others are found in fungi, under the bark of trees, and as the guests of termites and ants. One of the bark-inhabiting species is taken up in this study.

Nudobius pugetanus Casey

The genus *Nudobius* was erected by Thomson (1860) and is very closely related by *Xantholinus* of Serville (1825). It has been treated, in fact, by some authors as a subgenus of *Xantholinus.* Ganglbauer (1895), Heyden (1906), and Casey (1906) recognized *Nudobius* as a separate genus of the tribe Xantholinini. Reitter (1909) treated *Nudobius* as a subgenus of *Xantholinus* and Kuhnt (1913) recognized only the genus *Xantholinus* Serv. (*Nudobius* Thoms.). Leng (1920) and Gusev (1928) recognize the genus *Nudobius,* and this is generally accepted at the present time. Casey's characterization of *Nudobius* is as follows:

> In many characters *Nudobius* is somewhat intermediate between *Eulissus* and allied genera and *Xantholinus,* but in the rapid medial deflection of the side margins of the prothorax, which unite the lower margin and do not continue separate therefrom to the apex, it is wholly isolated. The integuments are highly polished throughout, but the surface of the head and pronotum has, besides the normal punctures, a system of very minute sparse punctules, evenly distributed throughout. The punctures of the pronotum are notably fine, feeble, very sparse and inconspicuous throughout the genus *Nudobius* and are arranged in the two discal series, each containing some 5–7 punctures and an arcuate sub-marginal line, at each side, of nearly the same number.[11]

All the species of *Nudobius* are predators so far as is known and are found usually under the bark of trees killed by bark beetles. In Europe *Nudobius lentus* Grav. and *Nudobius collaris* E. are the best

[11] Casey, pp. 381, 384.

known. There are fifteen species listed in America north of Mexico and among them *N. cephalus* Say is the best known. In the West, Casey (1906) cites several species, but the distinguishing characters are not very well marked.

Nudobius pugetanus was described by Casey (1906) from Oregon and Washington. This species has been confused with *N. cephalus* Say, the eastern species. *N. cephalus* Say has been, in fact, incorrectly reported from the West. *Nudobius pugetanus* Csy. is found in Washington, Oregon, and northern California and the chief characters which separate it from the other California species are length of body and shape of prothorax. Specimens collected by the writer have been carefully compared with named specimens of *N. pugetanus* Csy. in the Blaisdell collection in the California Academy of Sciences by Van Dyke and the writer. Specimens were also carefully compared with *N. corticalis* Csy. collected by Van Dyke in the hills back of Oakland, California, under the bark of Monterey pine. The difference between this species and *N. pugetanus* Csy. is in the size of the head, which is broader in proportion to length in *N. pugetanus* Csy. This is merely a varietal difference and does not justify ranking *N. corticalis* as a separate species. The other characters given by Casey are not evident enough to separate them. *N. pugetanus* Csy. is a predaceous insect found in bark beetle egg galleries.

DESCRIPTION OF STAGES

Figure F

Eggs.—Color white; length slightly more than 1 mm.; about one-half as wide as long; shape oblong, slightly broader at one end.

Larva.—Head ferruginous red, prothorax lighter red, body creamy white; length when mature 8–10 mm.; "head protracted, posteriorly constricted with a closed, ringshaped collar around a posteriorly directed foramen; median epicranial suture distinct and slightly exceeding in length each of the frontal sutures; labrum and clypeus fused together and with the frons forming a projecting subrectangular nasale armed with 11 teeth, namely one smaller median tooth and on each side of this one large and sharp followed by three more obtuse teeth which gradually decrease in size exteriorly; epipharynx within a groove on the inner surface of nasale. Ocelli distinct, one on each side. Each antenna inserted in the anterior margin of frons, four segmented, with a well developed distal segment, almost half as long as the subdistal and with a minute sensory cone outside the base of the distal segment. Mandible long, sickle-shaped, simple without retinaculum and without penicillus. Maxilla with stipes free and cardo inserted in some distance behind the anterior ventral margin of epi-

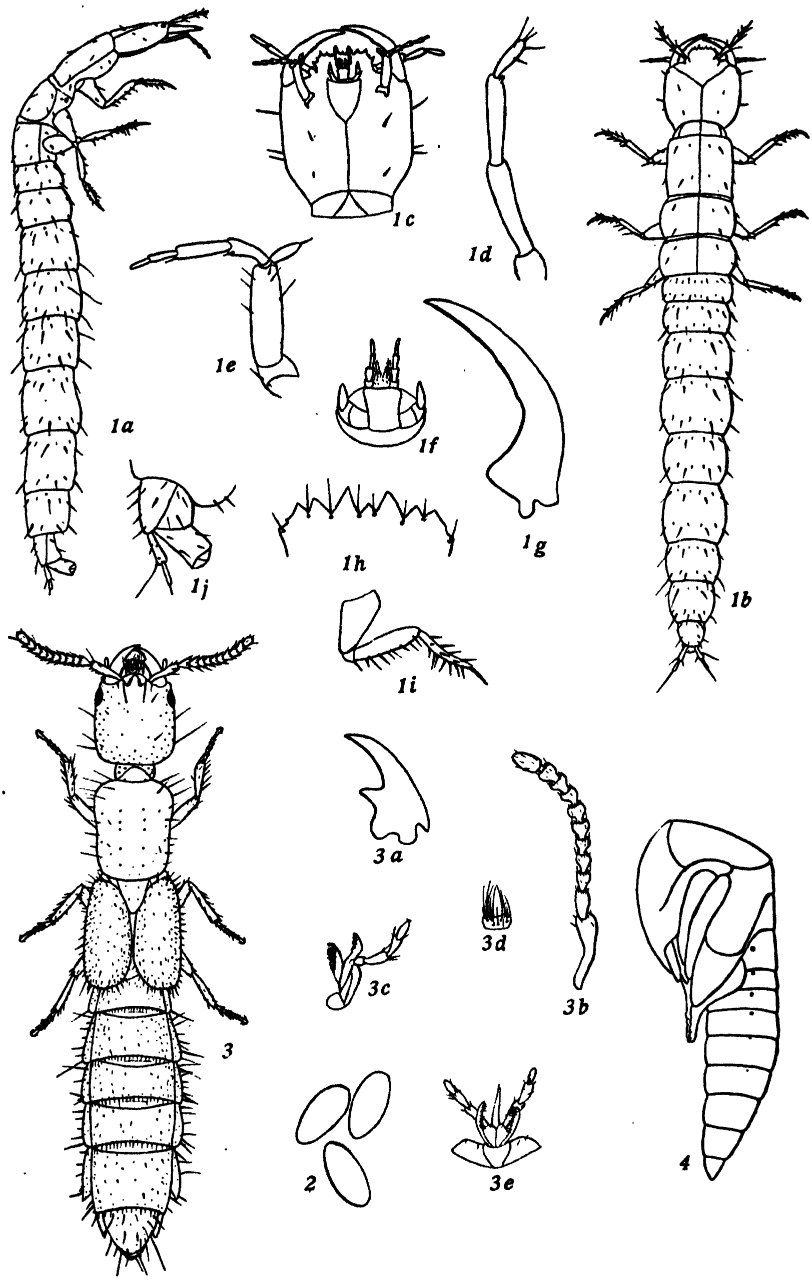

Fig. F. *Nudobius pugetanus* Csy.

1*a*, larva (lateral aspect); 1*b*, larva (dorsal aspect); 1*c*, head; 1*d*, antenna; 1*e*, maxilla; 1*f*, labium; 1*g*, mandible; 1*h*, clypeus; 1*i*, leg; 1*j*, lateral aspect of pygidium; 2, eggs; 3 adult (dorsal aspect); 3*a*, mandible; 3*b*, antenna; 3*c*, maxilla; 3*d*, labrum; 3*e*, labium; 4, pupa.

cranium; maxillary palpus four-segmented, maxillary lobe free, consisting of a single, subcylindrical segment with a terminal seta. Pregular plate subcordiform with each front corner prolonged into a horn-shaped projection; mentum soft and dome-shaped; prementum elongate, subrectangular, slightly hourglass-shaped; labial palpus three segmented with a large basal membrane; ligula long, slender and styliform."

"Prothorax smaller than head, somewhat longer than wide. Meso- and metathorax together only slightly longer than prothorax, each thoracic segment dorsally covered with a shield. Legs fairly stout and long, five segmented with coxa free, long and conical, tarsal segment claw-shaped, very slender, slightly curved and pointed; entire leg armed with many spine-like hairs. Abdomen elongate, somewhat depressed; dorsal, pleural and ventral regions of each of the anterior eight segments bearing thin, shining shields, sparsely beset with short hairs, dorsal shields paired and well separated by intermedian soft skin; each of the dorsal shields with a small, round, dark spot anteriorly to the spiracle; ninth abdominal segment with a pair of two segmented cerci; proximal segment of each cercus straight, not much longer than the distal segment; tenth abdominal segment as long as ninth but much narrower, subcylindrical and furnished with two pairs of long, pyriform, retractile and finely asperate anal sacs. Spiracles small, circular; nine pairs present, all lateral. Setae all simple and pointed, never terminally enlarged."

Pupa.—Color dark yellow; anterior end truncate with head and thoracic portions closely appressed; abdomen with nine segments and pointed at the tip.

Adult.—Length 7.9–9.2 mm.; width 1.25–1.4 mm.; black, shining; elytra rufous, legs pale testaceous; head large, well developed; front distinctly though finely punctured between frontal grooves, rather coarsely punctulate toward the sides, the punctures elongate, strong, more rounded, and close set beneath; becoming less distinct and sparser toward base; prothorax distinctly narrower than the head, longer than wide, narrowed posteriorly from the apex; elytra as long as the prothorax and wider; longer than wide, finely punctured; punctures of the medial series stronger than the others.[12]

LIFE-HISTORY AND HABITS

Nudobius pugetanus Csy. adults enter the bark of dead yellow pine by means of the bark beetle ventilation holes in much the same manner as the other secondary insects. The larvae and adults which alone represent the overwintering stages, remain dormant under the bark until favorable weather conditions, when they again become active. In the Modoc region the adults begin to lay eggs during the first part of June. The eggs are laid at the sides of the bark beetle egg galleries,

[12] Description of adult adapted from Casey, p. 382.

always singly, which is perhaps of considerable importance for insuring protection against being devoured by the newly hatched active predaceous larvae which hatch out within ten days to two weeks and very soon afterward search for food material. Their development is rapid and the first of them reach maturity and pupate by the middle of August. The summer generation of adults is in evidence about the first of September. These either enter trees which have been killed during the summer or remain where they were reared to start a new brood and to overwinter.

The larvae which spend the winter under the bark develop to maturity and pupate by the latter part of June. The adults emerge after two weeks and enter the first summer brood trees attacked by *Dendroctonus brevicomis* Lec. The *D. brevicomis* Lec. brood at this time is in the fully grown larval and pupal stages. A brood of *N. pugetanus* Csy. larvae is started by the middle or latter part of August and is half-grown before hibernation takes place.

The duration of each stage of development during the summer is as follows: eggs, ten days to two weeks; larvae, six to eight weeks; and pupae, two weeks, or a total of ten to twelve weeks for a single generation. The rapidity of development is dependent on the temperature primarily and on the food supply. Some develop faster than others and thereby no considerable large numbers of adults emerge at any given time. The eggs of a specific generation are deposited over a period covering from three to four weeks, thus creating a variety of ages in a single generation. Any stage of the insect may be found during midsummer under the bark of trees which were killed the previous season, but insects in the stages represented in trees killed by bark beetles during the summer do not appear before the latter part of July, or within a month after a successful bark beetle attack. In general, one complete generation is accomplished between June and September, starting from eggs and ending as adults. One complete generation takes place starting from half-grown larvae in May and ending as half-grown larvae in September. It is clearly indicated that one generation of this insect is produced each year, in one case starting as adults and ending as adults, and in the other case starting as larvae.

The habits of the larvae have already been indicated. They are very agile predators and are able to catch their prey with great ease. (The relatively long legs enable them to run after and grasp their prey.) Many of the small coleopterous and dipterous larvae under

the bark are preyed upon by this insect. The larvae have also been noted to prey upon each other, as well as on the larvae of *Othnius lugubris* Horn, *Platysoma punctigerum* Lec., and dipterous larvae. The habits of the adults are very similar to those of the larvae. In addition to feeding on larvae they are also predaceous on small adult beetles under the bark.

Nudobius pugetanus Csy. is not considered important as an economic insect. It has been stated that it enters a tree within a month following the attack of *Dendroctonus brevicomis* Lec. At this time the bark beetles have finished laying eggs and have already started to leave the tree. Consequently *N. pugetanus* Csy. could not enter in as an enemy of *D. brevicomis* Lec. It preys wholly on the secondary insects under the bark and may destroy some of the beneficial forms.

LITERATURE CITED

BLATCHLEY, W. S.
1910. Coleoptera of Indiana (The Nature Publishing Company, Indianapolis, Ind.).

CASEY, THOS. L.
1906. Observations of the Staphylinid groups Aleocharinae and Xantholinini chiefly of America. Trans. Acad. of Sci. St. Louis, **16**: 380–384.

DE MARSEUL, S. A.
1853. Essai monographique sur la Famille des Histerides. Ann. Soc. Ent. Fr., **22**:248–286, pl. 4e.
1856. *Idem*, **25**:259–279, 1 pl.

ERICHSON.
1834. Ubersicht der Historoides. Jahrb. Insektenkunde, **1**:83–208.

ESCHERICH, K.
1923. Forstinsektenkunde Mitteleuropas, **2**:48–49.

GANGLBAUER, LUDWIG
1895. Die Kafer von Mitteleuropa (Wien), pp. 475–477.

GEBIEN, H.
1911. Coleopterorum Catalogus (W. Junk), pars. 28, **24** III, pp. 412–417.

GUSEV, V. I.
1928. Beneficial insects found in trees infested with bark beetles. Bul. Inst. of Forestry, Leningrad (Petrograd Liesnoi Institut; Izvestiia), **36**:133–153.

HANDLIRSCH, DR. A.
1921. Schröder's Handbuch der Entomologie, **3**, chap. 7, Palaeontologie, p. 230.
1923. *Idem*, **3**:580–581.

HEYDEN, L. V., REITTER, E., WEISE, J.
1906. Catalogus Coleoptorum Europae, pp. 161–162.

HOLDHAUS, DR. KARL
1927. Die geographische Verbreitung der Insekten (Fortsetzung), *in* Schröder's Handbuch der Entomologie, **2**, chap. 7, p. 688.

HOPKINS, A. D.
1893. Report on investigations to determine the cause of the unhealthy condition of eastern Spruce from 1880–1893. U. S. Dept. Agr., Bul. 28, ser. 2.

HORN, G. H.
1870. Description of new species of Histeridae. Trans. Am. Ent. Soc., **3**:141.
1870. Revision of the Tenebrionidae of America north of Mexico. Trans. Am. Philos. Soc., **14**:253–404.

JACQUELIN DU VAL, C., and FAIRMAIRE, L.
1857. Genera des Coleopteres d'Europe, **6** (Chez a Deyrolle naturaliste, Paris), Introd., pp. xxxiv, xxxv, xli.

KLEINE, R.
1908–09. Die europaischen Borkenkafer und ihre Feinde aus den Ordnungen der Koleopteren und Hymenopteren, *in* Ent. Bl. **4** and **5**.

KUHNT, P.
1913. Illustrierte Bestimmungs—Tabellen der Kafer Deutschlands. Stuttgart.

LACORDAIRE, TH.
1859. Histoire naturelle des insectes. Genera des Coleopteres, 5:338.

LECONTE, J. L.
1861. New species of Coleoptera inhabiting the Pacific district of the United States. Proc. Acad. Nat. Sci. Phila., November, p. 343.
1878. Coleoptera of Florida. Proc. Am. Philos. Soc., **17**:423–424.

LECONTE, J. L., and HORN, G. H.
1883. Coleoptera of North America (Smithsonian Institution, Washington, D.C.), p. 147.

LENG, C. W.
1920. Catalog of the Coleoptera of America north of Mexico.

NÜSSLIN, Dr. OTTO
1913. Leitfaden der Forstinseklenkunde (Berlin), p. 111.

OREST, MARCU.
1926. Beitrage zur Generationsfrage einiger Borkenkafer. Zool. Anzeiger, **67**(3, 4): 81–87.

PACKARD, A. S.
1890. Fifth report of the U. S. Entomological Commission (Wash., Gov't Print. Off.), p. 18.

PERRIS, E.
1852–1862. Histoire des insectes du pin maritime. Ann. Soc. Ent. Fr., 1852, **21**:491–522; 1853, **22**:552–664, 3 pls.; 1854, **23**:85–160, 593–646, 3 pls.; 1856, **25**:173–257, 423–486, 2 pls.; 1857, **26**:341–395, 2 pls.; 1862, **31**:173–243, 2 pls.

PERSON, H. L.
—— Study of the clerid *Thanasimus nigriventris* Lec. with notes on other insect enemies of western pine bark beetles. (MS, 1928.)

REITTER, E.
1909. Fauna Germanica. Die Kafer des deutschen Reiches (Stuttgart), pp. 136–137.

SAALAS, U.
1917. Fichtenkäfer Finnlands, **1** (Helsinki).
1923. Fichtenkäfer Finnlands, **2** (Helsinki).

SCHIÖDTE, I. C.
1862–1883. Naturhistorisk Tidsskrift, ser. 3, **1–13** (Copenhagen, Denmark).

SERVILLE, J. G. A.
1825. Encyclopediae methodique, **10**, Entomologie (Paris. See under Olivier).

SHARP, D.
1899. Cambridge natural history, **6**:263–264.

SIMPSON, L. J.
1929. The seasonal history of *Polygraphus rufipennis* Kirby, Canadian Entomologist, **61**:145–151.

STEBBING, E. P.
1914. Indian forest insects. London.

THOMSON, C. G.
1860. Skandinaviens Coleoptera, etc., Lund, **2**:188.

STUDIES OF THE ANATOMY AND HISTOLOGY OF THE REPRODUCTIVE SYSTEM OF THE FEMALE CODLING MOTH, CARPOCAPSA POMONELLA (LINN.)

BY

STUART L. ALLMAN[1]

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INTRODUCTION

In an investigation of the literature dealing with the codling moth, it was surprising to find that such a well-known insect, and such a destructive pest, has been but little studied from the morphological and histological standpoints. Such work as has been carried out has dealt mainly with the larva or caterpillar, the injurious stage of this insect, in which it causes much damage to walnuts, pears, and especially to apples. Bordas (1910), in his paper entitled "Les glandes céphaliques des chenilles de Lepidoptères" dealt with the silk and

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mandibulary glands and Montgomery (1900) wrote "On Nucleolar Structures of the Hypodermal Cells of the Larva *Carpocapsa.*" Lopez (1929) has added to these contributions with his paper entitled "Morphological Studies of the Head and Mouthparts of the Fully Grown Codling Moth Larva, *Carpocapsa pomonella* (Linn.)." McIndoo (1929) in "Tropisms and Sense Organs of Lepidoptera" deals with both the larval and the adult codling moth and records a number of sensoria in each form. Heinrich (1926) in the "Revision of the North American Moths of the Subfamilies Laspeyresiinae and Olethreutinae" deals extensively with the male and female genitalia of these groups and incidentally with those of the codling moth. He cites also an important paper by Pierce and Metcalfe (1922) on "Genitalia of the Group Tortricidae of the Lepidoptera of the British Islands" in which the genitalia form the main basis of classification.

Investigations on the economic phases have been numerous since the earliest report in literature of this pest. The total of these investigations would undoubtedly far exceed those for any other pest, even though, according to Smith (1926), "Something over two hundred state and federal bulletins and major papers or serial publications have appeared during the past twenty-five years." At the present time, as a result of the activities of *Carpocapsa pomonella,* approximately forty entomologists are carrying out experimental work on this pest, dealing with control, spray residues, bionomics, and mass production of parasites.

The adult insect is an inconspicuous moth which flies about the orchard, at dusk, depositing its eggs on the leaves and fruits. The knowledge of this habit is of importance, both in respect to its control and to the functioning of the egg-laying female. Moths do not deposit eggs unless certain environmental factors are favorable for oviposition. Of these factors, temperature has received the most attention and it is now conceded that little or no deposition takes place unless the temperature, at dusk, is above 60° F; in fact, certain control measures are timed on this basis. Herms (1929) has drawn attention to the factor of light intensity and there are indications that active deposition takes place after sunset when the light intensity is approximately three to four-tenths of a foot candle. In view of the restricted time for egg deposition and the fact that moths are capable of laying over one hundred eggs, it is a matter of some interest to study the possible effects of such restrictive factors on the functioning of the moths.

The egg-laying female has, in the past, received some attention from investigators using light and bait or "hootch" traps as control measures for the adults. In these studies, the capture of gravid females is of the utmost importance, and in order to recognize this condition in the female, one must have a certain degree of familiarity with her anatomy.

Acknowledgments

I wish to take this occasion to acknowledge my indebtedness to Professor E. O. Essig, Dr. E. C. Van Dyke, and Dr. S. F. Light for general supervision and revision of manuscript; to Dr. S. B. Freeborn for assistance, criticism, and correction of manuscript, and to Mr. J. F. Lamiman for suggestions. I am also indebted to Mr. A. D. Borden for the collection of moths used in these studies.

METHODS

The moths were first anaesthetized with chloroform and subsequently dissected in physiological salt solution. Bouin's picroformol was used as the fixing reagent and all material was imbedded in paraffin. In some instances, the abdomens of freshly emerged females were fixed entire. In this manner, it was possible to obtain sections of the abdomen without any special softening of the chitinous body wall and the organs were thus demonstrated *in situ*. Sections were cut from 5 to 15 microns in thickness. Heidenhain's iron-alum haematoxylin and Delafield's haematoxylin counterstained with eosin were the stains generally used. Mallory's aniline blue was employed in one series to demonstrate the presence of chitin in the various organs.

A number of specimens were cleared in dilute caustic potash and the abdomens mounted to demonstrate the segmentation, the external openings, and the chitinous intima of organs derived from the ectoderm. Some specimens were stained in magenta, acid fuchsin, or picric acid, and the exoskeleton cut away leaving the chitinous linings of the reproductive system and the hindgut. In this manner the ectodermal origin of the bursa copulatrix, spermatheca, vagina, and two sets of accessory glands, was clearly illustrated.

THE REPRODUCTIVE SYSTEM: GROSS ANATOMY

The External Openings

The reproductive system, in common with the more highly specialized Lepidoptera, has two external openings (pl. 5). The eggs are deposited at the vaginal aperture, immediately adjacent and anterior to the anus. The copulatory aperture is located ventrally, on the seventh segment of the abdomen and in this respect seems peculiar, in that the aperture of other specialized forms lies in the membrane between the seventh and eighth segments or at the anterior end of the eighth sternum (fig. A). The chitinous plates underlying the seventh

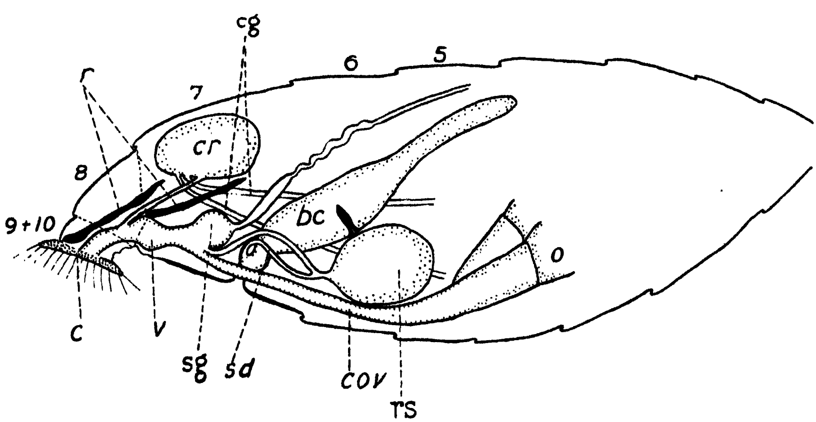


Fig. A. Lateral view of the abdomen and reproductive organs. *bc*, bursa copulatrix; *c*, cercus; *cg*, colleterial glands; *c. ov*, common oviduct; *cr*, colleterial reservoir, with ceca; *o*, ovariole; *r*, internal chitinous rods; *rs*, spermatheca or receptaculum seminus; *sd*, seminal duct (also extends between spermatheca and vagina); *sg*, single or spermathecal glands and cecum; *v*, vagina. Diagrammatic. × 24 (approx.).

segment are definitely demarcated into two sections. A broader, anterior plate has two backward wedge-shaped extensions and surrounds on three sides a rectangular plate carrying the copulatory aperture at its anterior edge. It would thus appear that the sternite of the eighth segment has become associated with that of the seventh and thus come to lie entirely within the seventh segment in the typical asymmetrical arrangement figured (fig. B).

This assumption is supported by the lack of divisions in preceding sternites, and a study of the segmentation and genital openings of the pupa. Ten segments are present in the abdomen of the pupa and a single genital opening appears as a longitudinal slit crossing the eighth and extending into the ninth sternite (fig. C). The ninth

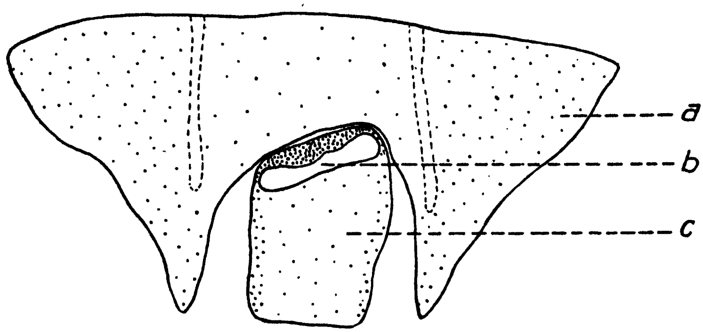


Fig. B. Sternites underlying the seventh abdominal segments. *a*, seventh sternite; *b*, copulatory aperture; *c*, eighth sternite. Camera lucida drawing. × 53.

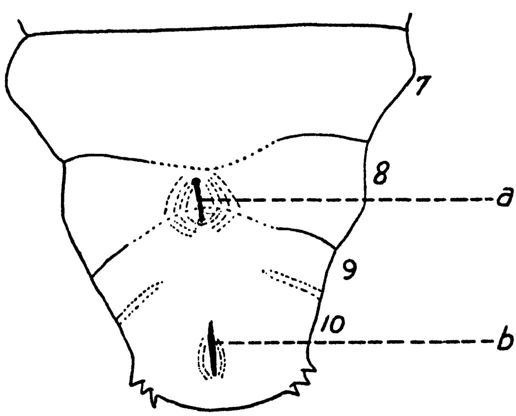


Fig. C. Ventral view of tip of abdomen of pupa. *a*, genital aperture; *b*, anus. Camera lucida drawing. × 31.

sternite is very indistinct ventrally, and pushes forward somewhat into the eighth, which is described by Jackson (1890) as customary in the female pupae of the Heterocera. The eighth tergite in the adult consists of an almost complete chitinous ring, bearing a pair of internal chitinous rods; it is separated from the preceding tergite by a wide area of membrane. This extensive membrane formation, the fusion of segments nine and ten, and the almost complete telescoping of segments eight, nine, and ten, readily admits of the forward movement of the eighth sternite.

According to Imms (1925), the copulatory aperture corresponds with the vaginal opening in other orders, and the opening of the common oviduct, or vagina, has migrated backward to take up a secondary position on the ninth sternum. Only one genital aperture appears in the pupa, but this extends into both segments eight and nine and gives some external indications of the two ultimate openings in the adult. In some forms, two distinct openings are present, while in many only the single opening, above cited, is apparent. In a very few exceptional cases two distinct openings appear in forms normally showing the single linear aperture (Jackson, 1890).

THE OVARIES

The ovaries are large and conspicuous and fill up the major portion of the abdominal cavity, lying on either side of the alimentary tract. Each ovary consists of four ovarioles which extend forward toward the base of the abdomen and then pass backward becoming coiled, vertically, and uniting at their somewhat truncated tips. In some cases the ovarioles appear to unite in pairs but generally the four ovarioles have a common termination. The terminal filaments of the ovarioles are difficult to demonstrate and no common suspensory ligament is apparent. Each set of ovarioles ends freely in the body cavity, attached to the abundant fat body, and there is no common median supporting ligament such as is present in many other forms. The ovarioles are abundantly supplied with tracheae from the fourth and fifth pairs of abdominal spiracles.

The four ovarioles, on either side, unite at their bases and lead into the single oviducts.

THE GENITAL DUCTS

The short single oviducts, arising from the bases of the ovarioles, unite to form a considerably longer common oviduct. This leads backward and is continuous with a larger and differentiated duct, the vagina. The vagina is dilated laterally in its median region and finally opens to the exterior between the cerci and immediately anterior to the anus. The vagina also has a considerably swollen portion, at its inner end, which marks the point of entrance of the single or spermathecal gland.

No exserted ovipositor is present in the adult moth, but the exsertible portion is visible in developing pupae, when it projects considerably between the cerci. In freshly emerged females the terminal abdominal segments are much telescoped and even the cerci are retracted, thus giving the tip of the abdomen a hollow aspect from the ventral side.

The separate developments of the single oviducts and the common oviduct plus the vagina are also evident in the pupal condition when the line of union is clearly demarcated.

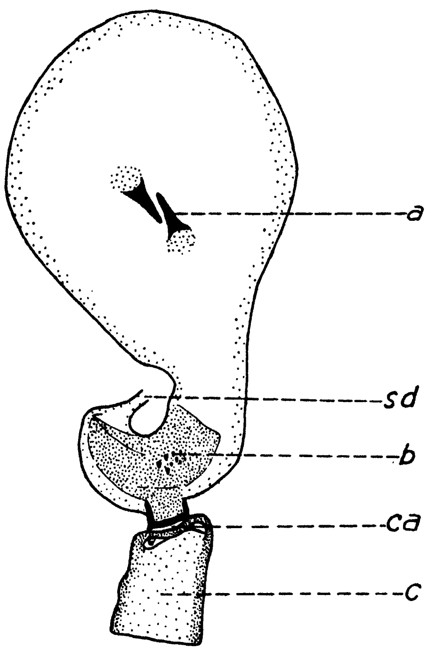


Fig. D. Cleared specimen of bursa copulatrix and eighth abdominal sternite. *a*, chitinous funnel; *b*, small spines on dorsal wall of neck; *c*, eighth sternite; *ca*, copulatory aperture; *sd*, seminal duct. Camera lucida drawing. × 32.

The Bursa Copulatrix

The bursa copulatrix is the most conspicuous organ with the exception of the ovaries. It consists of a large, somewhat flattened pouch, with its opening on the eighth sternite (fig. D). The bursa extends forward into the fourth segment and is usually dark in color. The chitinous lining is very pronounced about the opening, and the dorsal portion also bears a number of small spines. About the middle of the bursa, the wall is invaginated internally so as to give two long, heavily chitinized, funnel-shaped rods. One rod appears on the dorsal wall,

while the other is ventral. A very pronounced muscular coat is evident and the muscles seem to radiate somewhat from the broadened bases of these rods.

In the Lepidoptera, the bursa copulatrix appears in a number of morphologically different forms. In *Bombyx mori* Linn. the bursa copulatrix has no muscular coat, the sperms moving by their own motility to the muscled spermatheca, which regulates the passage of sperms at the proper time. Burgess (1880) described a muscular bursa in *Danais archippus* (Fabr.), and Stitz (1901) a similar organ

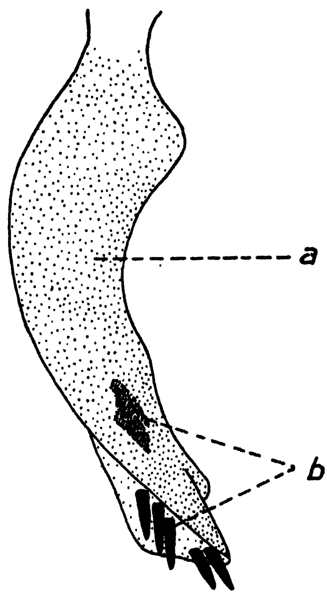


Fig. E. Lateral view of edeagus of male. *a*, sheath; *b*, chitinous spines. Camera lucida drawing. × 91.

in some of the microlepidoptera, e.g., *Tortrix viridana* Linn. and *Crambus pratellus* Linn. Stitz also described internal chitinous thickenings in the walls of the bursa and attributes to Hagen (1882) the first discovery of such structures in two species of Tineids. In his descriptions he refers to these structures as "plates" and "lamina dentata" and they would thus appear to differ considerably in their structure from the narrow funnels present on the bursa of *Carpocapsa pomonella* (Linn.).

The function of these rods is not readily apparent and certainly does not seem to be for support, as they end freely in the cavity of the bursa and the walls of this organ are in themselves strongly chitinized and muscled. A study of the edeagus of the male reveals two sets of

conspicuous spines. The first set is situated at the distal end, with a pair of apical spines, and in close association a further series of three similar spines. The second set consists of three spines and is withdrawn within the sheath of the edeagus (fig. E). A possible connection between these spines and the rods of the bursa is apparent but no definite information on this point is available as considerable difficulty is experienced in mating this species unless large numbers are procurable. Pairs of moths in copula have been previously noted, and in some instances mating was prolonged, obviously an unusual condition denoting a strong coupling arrangement (Allman, 1928).

The Spermatheca

The spermatheca is a thin-walled globular sac without the colored, conspicuous, chitinous lining usually present on this organ. It is situated on a short offset of the seminal duct leading from the bursa copulatrix to the vagina. The walls do not have the well developed muscular coat which is sometimes present, for the movement of the sperms.

The Seminal Duct

The seminal duct leads from the base of the bursa copulatrix and opens into the vagina just before the oviduct. Situated on a short offset, in the middle region, is the globular spermatheca. In freshly developing pupae the seminal duct opens directly into the common oviduct just prior to the latter's entrance to the vagina, but in the adult condition a slight modification is apparent.

The seminal duct is practically uniform in width throughout its entire length and in this respect agrees with the findings of Stitz (1901) concerning *Tortrix viridana* Linn. Petersen and Luckhart, on the other hand, have found a considerable dilation of the seminal duct in some species of Tortricids (Stitz, 1901).

The Accessory Glands

A pair of colleterial glands and a single gland open into the vagina. The colleterial glands consist of a pair of long ceca opening into a pitted, thin-walled, and reniform reservoir. A single duct leads from this reservoir and enters the vagina, dorsally, in the region of its median enlargement. The function of these glands is probably the production of the cement to fasten the eggs to the leaves or fruit.

The single gland also consists of an elongated cecum, entering a heavily muscled dilated portion of the vagina. Just prior to this entrance the gland is differentiated into a straight muscled section which, in turn, leads into a thin-walled, dilated, and spirally coiled portion, apparently functioning as a reservoir (fig. F). This reservoir leads into the long cecum which forms the major portion of the gland.

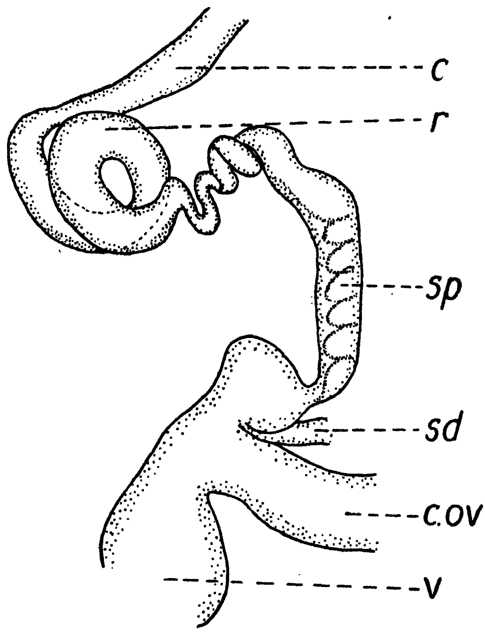


Fig. F. Lateral view of spermathecal gland and vaginal connections. *c*, caecum; *c. ov*, common oviduct; *sd*, seminal duct; *sp*, single or spermathecal gland with spiral lumen; *r*, reservoir of single or spermathecal gland; *v*, vagina. Camera lucida drawing. × 53.

In the muscled section the lumen has a pronounced spiral arrangement. The single gland probably corresponds to the spermathecal gland, commonly found in association with that organ, and its opening is adjacent to that of the seminal duct.

The ceca of both sets of glands are considerably longer than the abdomen of the moth and are consequently much coiled in the fat body. They were also strongly adhesive to instruments used in the dissection of the moths.

The Internal Rods

Two pairs of internal, elongated, chitinous rods are produced, laterally, in the terminal segments of the abdomen. The outer pair is produced from the tergite of the eighth segment and the inner pair probably constitutes a remnant of the ninth tergite. The inner

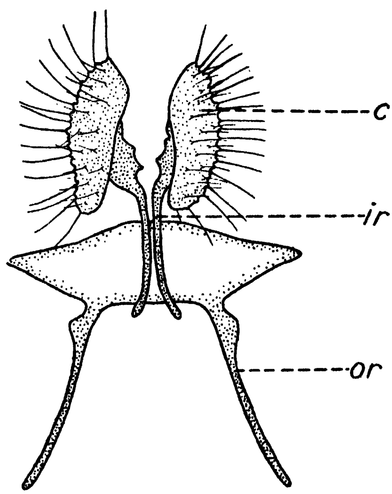


Fig. G. Ventral view of heavily chitinized sections at the tip of the abdomen. *c*, cercus; *ir*, inner rod; *or*, outer rod attached to eighth abdominal tergite. Camera lucida drawing. × 35.

rods are much flattened and broadened at their posterior ends and partly cover the vagina in its dorsal and lateral aspects (fig. ~~H~~). G
Both sets of rods serve for the attachment of a large series of muscles which cause the telescopic and ovipository movements of the abdomen. The inner set may also function in assisting in the act of oviposition (Tillyard, 1926).

HISTOLOGY OF THE REPRODUCTIVE SYSTEM

Figure H

The Ovaries

Each ovary consists of four polytrophic ovarioles, which are, in turn, divided into three distinct regions, viz., the terminal filament, the germarium or germinative chamber, and the vitellarium which forms the major portion. The ovariole is bounded by an outer peritoneal membrane, followed by a basement membrane and a layer of epithelial cells. The terminal filament is formed by a prolongation of the peritoneal membrane and functions as a suspensory ligament. The germarium is without the layer of epithelial cells and contains a mass of undifferentiated cells from which the egg and the yolk cells are formed. The main portion of the ovariole or vitellarium contains the developing eggs and the attendant yolk or nurse cells. The epithelium encloses each oocyte into a definite sac or follicle, and constrictions between the egg cells proper and the nurse cells are lacking.

The epithelial layer is very pronounced in the case of the developing eggs, but becomes less distinct at the bases of the ovarioles where the mature eggs are situated. In the case of the oldest eggs the epithelium becomes very thin and flattened, with conspicuous elliptical nuclei. In addition to this change the chorion secreted by the epithelial cells, and the thin vitelline membrane developed from the egg cell are apparent. The chorion is very pronounced and is remarkable for its apparent looseness about the egg. The egg when deposited is exceedingly flat and thus differs greatly in shape from the egg in the ovariole. This fact may be responsible for the apparent excessive development of chorion.

The greatest number of eggs in a single ovariole showing full development of the two membranes was five and from this it was apparent that a moth would have, at one time, approximately forty mature eggs. This figure is considerably in excess of the actual daily deposition usually recorded in laboratory experiments. The female moth is generally stated to lay about one hundred eggs over a deposition period of approximately twelve days. In one instance, a single

female moth, previously under observation, laid ninety-eight eggs over a period of five days, of which fifty-five were deposited on one day. It is therefore apparent that the limit of mature eggs in the ovarioles may be in excess of the number stated. In the instance cited, however,

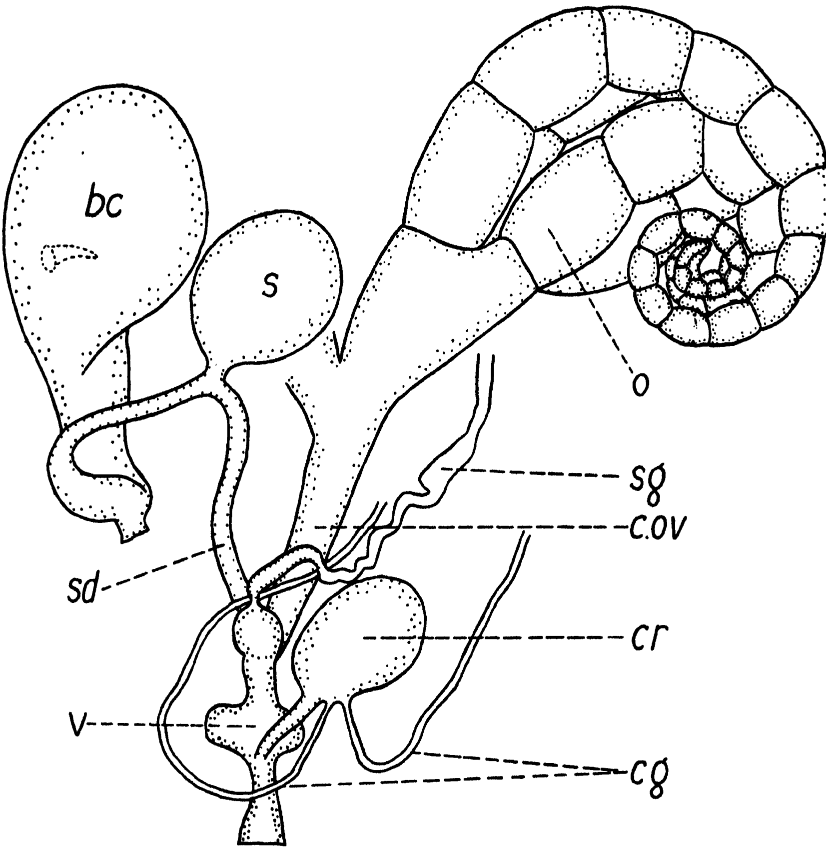


Fig. H. Dorsal view of reproductive system, with bursa copulatrix removed to the left. *bc*, bursa copulatrix; *cg*, colleterial glands; *c. ov*, common oviduct; *cr*, colleterial reservoir; *o*, ovariole; *s*, spermatheca; *sd*, seminal duct (from spermatheca to vagina; *sg*, single or spermatheeal gland; *v*, vagina. Diagrammatic. × 33 (Approx.).

a period of seven days elapsed from emergence to the first deposition, consisting of fifty-five eggs, whereas the normal pre-oviposition period is two to three days and in many instances only one day.

The walls at the base of the ovarioles show a limited development of circular muscles, but the main portions are not strengthened in this manner.

The Genital Ducts

The oviducts are composed of an outer peritoneal membrane, overlying a sheath of muscles that are, in the main, circular. Inside this sheath is a layer of epithelium, resting on a basement membrane and secreting internally a chitinous lining (pl. 6). This chitinous lining in the single oviduct is often thrown into a regular series of minute folds, appearing as projecting points, which would allow of considerable expansion of this otherwise inelastic substance.

The eviduct is divided histologically into three portions, the single oviducts arising from the mesoderm, and the common oviduct and vagina, both of which are of ectodermal origin.

The single oviduct is characterized by an extensive development of epithelium and the lack of the pronounced inner lining of chitin found in the other portions. The greater development of epithelium undoubtedly serves as a valve to regulate the passage of eggs from the ovarioles.

The epithelium of the common oviduct is thrown into numerous folds, and usually one very pronounced longitudinal fold. The chitinous lining of this latter fold does not show the minute points seen in the much smaller and consequently less extended folds, and would thus rule out this character as a fixation reaction. In sections with the egg in course of passage, the oviduct appears as circular and very even in outline.

The vagina, which is continuous with the common oviduct, is distinguished by a relatively great development of circular muscles. This muscular coat again diminishes at the posterior end and the majority of the muscles are attached to the ventral side of the vagina from the body wall and would thus appear to function in the retraction of the ovipositor.

The epithelium is developed into a series of pronounced ridges in the region of the median lateral dilations of the vagina. This folding and lengthening of the epithelial layer has resulted in the formation of a pronounced dorsal pad of spindle-like cells with densely staining massed nuclei (pl. 7). The form of the epithelium together with the presence of the internal cavity indicates secretional activity. Moreover, the duct from the colleterial reservoir enters the vagina imme-

diately adjacent and below this dorsal pad and it would thus seem probable that the egg is retained for some time in this vestibule and prepared for its coat of cementaceous material before its extrusion.

A histologically similar pad of spindle-like epithelium is also developed in the dilation at the inner end of the vagina. This dilation and epithelium mark the entrance of the secretion from the single or spermathecal gland and in addition occur at the point of union of the vagina and seminal duct. This arrangement recalls that of the colleterial system with the exception that sperms and not eggs are under consideration.

The chitinous lining of the vagina becomes much pronounced on the ventral wall in its posterior and apparently exsertible portion.

The Bursa Copulatrix

The bursa copulatrix is strengthened by a great development of muscles and a very pronounced internal chitinous lining. The hypodermal cells secreting this layer are large and distinct with pronounced nuclei. They give rise to a colorless stratified dermal layer and an inner colored chitinous lining. These two layers are thrown into a regular series of minute folds, each fold corresponding to a single hypodermal cell. In the region of the copulatory aperture the dermal region becomes very much thickened and the muscular coat is lost.

The chitinous lining is further invaginated in the form of two elongated narrow funnels, one on each side of the bursa copulatrix (pl. 8*a*). These have a distinct serrated outline and are covered by a regular series of colored chitinous scales. A lumen is apparent in each of the funnels, but no opening at the tip into the cavity of the bursa was demonstrated. The hypodermal cells at the bases of these funnels are very minute, they lose their definite cell walls, and the nuclei are massed together and densely granulated (fig. I). This tissue extends into the lumen of the funnel and from its appearance seems to indicate secretional activity.

The muscles do not cover the bursa copulatrix uniformly, but radiate from the broadened bases of the funnels, becoming much more apparent as they proceed toward the edges and disappearing entirely in the neck region of the bursa. The attachment of muscles in the basal region of the funnels may have led to the internal development

of the rods as supporting structures to counterbalance the pressure exerted by the very heavy muscular coat. A similar unevenness of distribution and radiation of muscles was described by Stitz (1901) in *Tortrix viridana* Linn. He reports, however, a large ventral development of muscle in the region of the chitinous plates, whereas muscles are entirely lacking beneath the rods in *Carpocapsa pomonella.*

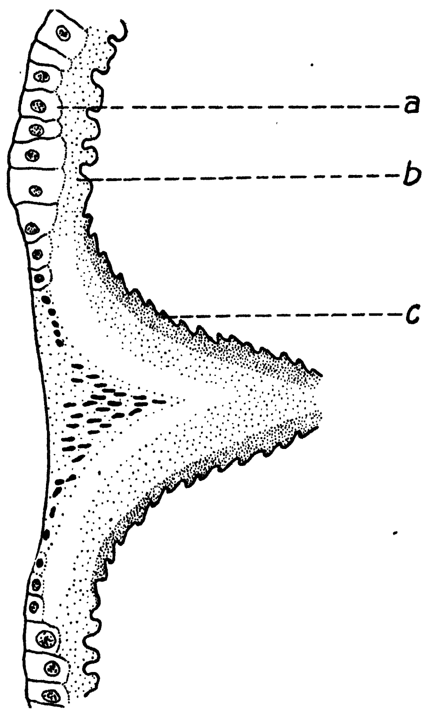


Fig. I. Cross-section of base of internal funnel of the bursa copulatrix. *a*, hypodermal cells; *b*, dermal layer; *c*, heavily colored, chitinized layer. Camera lucida drawing. × 400.

THE SPERMATHECA

The spermatheca consists of a simple globular sac whose walls are formed of chitinous lining, a single layer of epithelial cells, basement membrane, and peritoneal membrane. A weak development of muscles is apparent about the lower portion of the spermatheca at the entrance of the seminal duct, but the main sac is without reinforcement and is frequently collapsed in sections.

In situation and structure the spermatheca corresponds to the organ described by Balbiani as the bursa copulatrix of *Bombyx mori*

Linn. (*vide* Henneguy, 1904). In this latter form, however, an organ corresponding to the bursa copulatrix of the codling moth is not present. With this exception, the general arrangement of the genital apparatus is fairly comparable in the two species, but the single organ arising from the common oviduct is classified as the spermatheca with its accessory gland.

Owing to the difficulty of securing fertile females at the time of the season when this investigation was undertaken, none of the specimens showed sperms in either the bursa copulatrix or spermatheca. In a number of instances the contents of the spermatheca appeared as a rather dense series of folded membranes of unknown origin.

The Seminal Duct

The lumen of the seminal duct is lined with a heavy chitinous coat, diminishing in thickness, however, as it approaches the genital duct. An extremely pronounced development of circular muscles is also evident outside the median layer consisting of epithelium. The epithelium and chitinous lining are thrown into a series of six pronounced longitudinal folds, which is again most in evidence near the bursa copulatrix. The very heavy muscular coat is apparently developed for the movement of the sperms, as no such provision is made in the case of the spermatheca.

The Accessory Glands

Both sets of accessory glands are characterized by the presence of long ceca. Histologically, these ceca appear somewhat similar in both series, with the exception that those of the colleterial system are shorter and smaller in diameter. In transverse section, each cecum consists of approximately twenty wedge-shaped cells bounded exteriorly by a basement and finally a peritoneal membrane. Interiorly, a pronounced chitinous lining is secreted, being thicker in the case of the single spermathecal gland. This chitinous lining is traversed by small canals to allow the passage, into the lumen, of the secretion. The epithelial cells contain granulated, very deeply staining cytoplasm and very large nuclei. At their interior edges and around the chitinous lining are a number of smaller nuclei (pl. 8*b*). A similar structure has been described in the Orthoptera by Fenard (1896), who reports that these endothelial nuclei project into the lumen of the

ceca and completely close the cavity at the stage immediately preceding secretion. After secretion the epithelial cells show two concentric zones, one internal and deprived of granulations, and the other external and granulated. A somewhat similar condition is apparent in the colleterial ceca of the codling moth, but in addition to the internal cleared zone, other cleared areas are apparent around the periphery. The heavy chitinous lining would also prevent the obliteration of the lumen such as occurs in the Mantidae.

The walls of the colleterial reservoir consist of flattened epithelial cells, basement membrane, a thin sheath of muscular tissue and a peritoneal membrane. Internally, the epithelial layer secretes a thin chitinous lining. The wall is peculiar in the development of small intracellular refractile bodies. These are oval or pyriform and under high magnification show minute necks or canals which give access to the internal cavity of the reservoir. It is probable that these elements are unicellular glands and their prominent refractile nature due to secondary invagination and thickening of the chitinous lining of the reservoir. These bodies or glands extend up the nearer portion of the ceca but are absent from the main secreting section. Although the contents of the ceca appear homogeneous, the reservoir also contains a large amount of minute, darkly-staining particles usually evenly distributed throughout the sac, but in some cases also concentrated at the edges. In *Tortrix viridana* Linn., similar grains are present, but only as an interior lining of the walls (Stitz, 1901). It is possible that the unicellular glands may function in the secretion of these particles.

The single or spermathecal gland is differentiated into three sections, a straight muscled portion, a spirally coiled reservoir, and finally the long cecum already described.

The first section of the spermathecal gland has a very well developed muscular coat. The muscles are both longitudinal and circular and follow somewhat the spiral lumen. The epithelium has secreted a conspicuous chitinous lining, reinforced in such a manner as to form a clearly demarcated spiral canal. This organ obviously acts as a pump for the movement of the secretion (pl. 9).

The walls of the enlarged or storage section are formed of the same constituents, with the epithelium and chitinous lining thrown into numerous folds to allow for dilation, and the muscular coat very much reduced. This development of muscle is entirely wanting in the long cecum.

SUMMARY

1. The reproductive system consists of paired ovaries, single and common oviducts, vagina, bursa copulatrix, spermatheca, seminal duct, and accessory glands.

2. Two external openings are apparent, the copulatory opening lying in the seventh segment, but situated at the anterior end of the eighth sternite.

3. Two pairs of chitinous rods are developed internally for the attachment of muscles to aid in the telescopic movements of the abdomen.

4. Each ovary consists of four polytrophic ovarioles, without any median suspensory ligament.

5. The genital ducts consist of a single layer of epithelium, a basement membrane, a muscle coat of circular fibers, and a peritoneal membrane. The common oviduct and vagina are lined internally with chitin. A differentiation is apparent into single oviducts, common oviduct, and vagina.

6. The bursa copulatrix is developed to a great extent. A pronounced chitinous lining and muscular coat are formed. The chitinous lining is extended into two elongated narrow funnels, one each in the dorsal and ventral regions.

7. The spermatheca is a thin-walled globular sac without muscles.

8. The seminal duct has a series of longitudinal folds and a well developed muscular coat.

9. Two pairs of accessory glands of ectodermal origin are present. The two colleterial ceca lead into a reservoir whose walls are characterized by small refractile bodies, probably unicellular glands. The spermathecal gland is divisible into three portions, a cecum, reservoir, and a very heavily muscled pumping organ.

10. A capacity for the daily deposition of forty eggs is indicated.

LITERATURE CITED

Allman, S. L.
1928. The codling moth. Dept. Agr., New South Wales, Sci. Bull. 31, 36 pp., 11 figs.

Berlese, A.
1909. Gli Insetti (Milano), 1:x × 1004, 10 pls., 1292 figs. in text.

Bordas, L.
1910. Les glandes céphaliques des chenilles de Lepidoptères. Ann. Sci. Nat., 9:125–198.

Burgess, E.
1880. Contribution to the anatomy of the milk-weed butterfly *Danais archippus* (Fabr.). Boston Soc. Nat. Hist., Anniv. Mem.

Fénard, M. A.
1896. Sur les annexes internes de l'appareil génital femelle des Orthoptères. C. R. Acad. Sci., Paris, 122:1137–1139.

Hagen, H.
1882. Ueber ein eigenthumliches Organ in der Begattungstache zweier Tineiden. Zool. Anz.

Heinrich, C.
1926. Revision of the North American moths of the subfamilies Laspeyresiinae and Olethreutinae. Smithsonian Inst., U. S. Nat. Mus., Bull. 132, pp. v × 216, 76 pls.

Henneguy, L. F.
1904. Les Insectes (Paris), 804 pp., 4 pls., 662 figs. in text.

Herms, W. B.
1929. A field test of the effect of artificial light on the behavior of the codling moth, *Carpocapsa pomonella* (Linn.). Jour. Econ. Entom., 22:78–88.

Imms, A. D.
1925. A general textbook of entomology (Methuen, London), pp. xii + 698, 607 figs. in text.

Jackson, W. H.
1890. Studies in the morphology of the Lepidoptera. Trans. Linn. Soc. London, series 2, 5:143–186, 4 pls.

Lopez, A. W.
1929. Morphological studies of the head and mouth-parts of the fully grown codling moth larva, *Carpocapsa pomonella* (Linn.). Univ. Calif. Publ. Entom., 5:19–36, 16 figs.

McIndoo, N. E.
1929. Tropisms and sense organs of Lepidoptera. Smithsonian Miscellaneous Collections, 81:1–59, 16 figs.

Montgomery, T. H.
1900. On nucleolar structures of the hypodermal cells of the larva Carpocapsa. Zool. Jahrb. Abth. Morph., 13:277–368.

PETERSEN, W.
1904. Die morphologie d. generationsorgane d. Schmetterlinge. Mem. Acad. Sci. St. Petersbourg, **16**.

PIERCE, F. N., and METCALF, J. W.
1922. Genetalia of the group Tortricidae of the Lepidoptera of the British Islands, pp. 101, 34 pls.

SMITH, R. H.
1926. The efficacy of lead arsenate in controlling the codling moth. Hilgardia, **1**:403–453.

STITZ, H.
1901. Der Genitalapparat der Mikrolepidopteren. Zool. Jahrb. Abth. Anat., **15**:385–434, 5 pls.

TILLYARD, R. T.
1926. The insects of Australia and New Zealand (Angus & Robertson, Sydney), pp. xi + 560, 44 pls., 468 figs. in text.

EXPLANATION OF PLATES

All figures are camera lucida drawings or photomicrographs except where otherwise stated. The method of drawing and magnification is stated in the description of the individual figures.

PLATE 5

Ventral view of cleared abdomen. The opening of the bursa copulatrix is shown in the seventh segment and the genital opening indicated between the cerci. The relatively large size and heavy chitinous lining of the bursa copulatrix are evident. Photomicrograph. × 22.

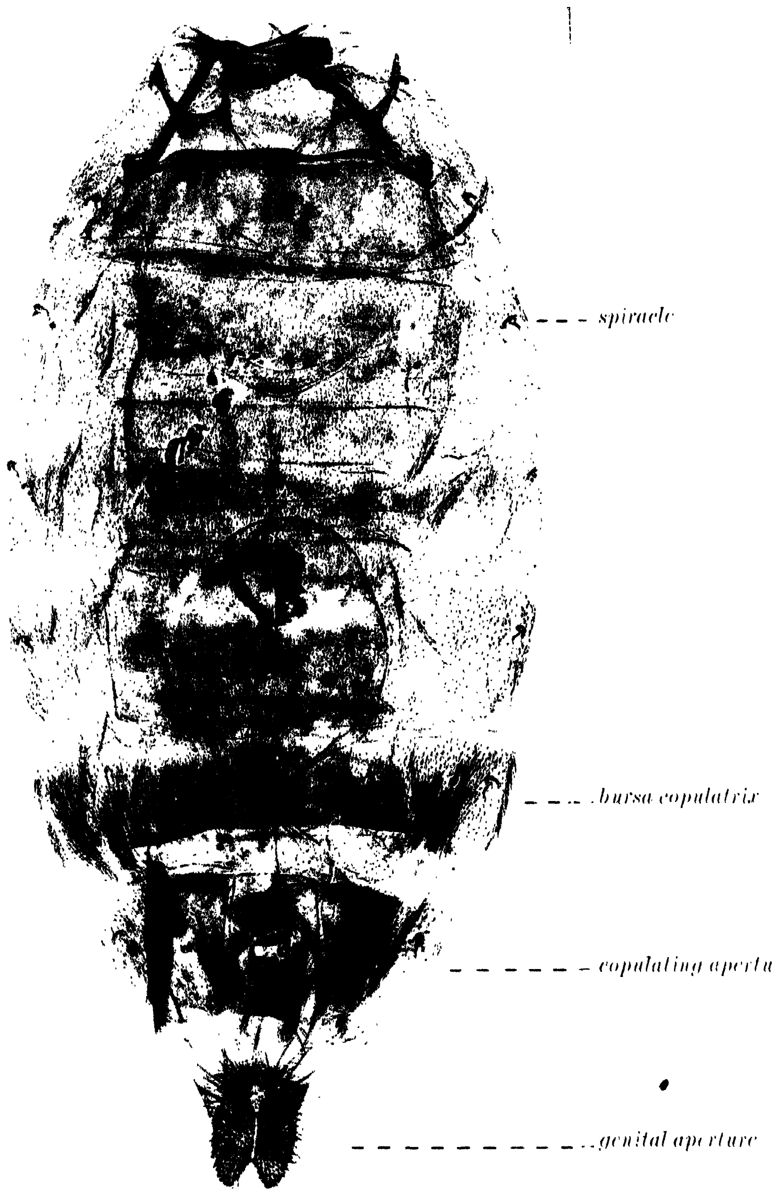

spiracle
bursa copulatrix
copulating apertur
genital aperture

PLATE 6

Cross-section of the common oviduct near its junction with the vagina. Note the folding of the epithelium, with the indication of a more pronounced dorsal fold, and the development of the circular muscles. The minute folding of the chitinous lining is not apparent in this section. Photomicrograph. × 353.

PLATE 7

Longitudinal section of the vagina. Note the median enlargement, with the development of a pronounced dorsal pad of spindle-like epithelium. The entrance of the duct from the colleterial reservoir is indicated adjacent to the basal portion of this specialized epithelium. The heavy muscle coat is pronounced about the main portion of the vagina, but is lacking at the outer end, which also shows the ventral thickening of the chitinous inner lining.

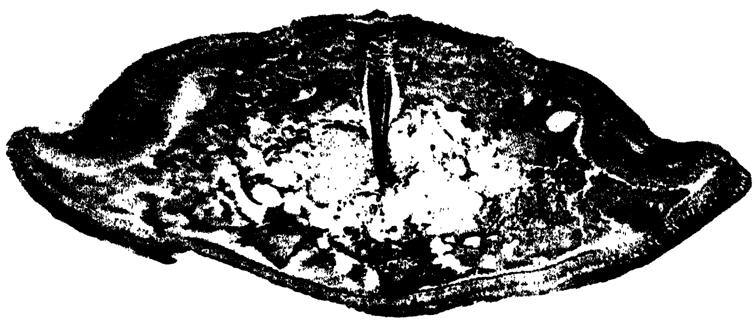
The large dorsal structure is apparently glandular but has no connection with either the hindgut (between this organ and the vagina) or the reproductive system, and may function as a scent gland. Photomicrograph. × 153.

PLATE 8*a*

Cross-section of the bursa copulatrix through one of the internal funnels. Note the serrated edge and scaliform covering of the funnel, together with a portion of the lumen. The lobed condition of the lining and the regular development of hypodermal cells of the bursa copulatrix are apparent. There is also the uneven development of the muscular coat, of which portion is missing on the ventral side. Photomicrograph. × 86.

PLATE 8*b*

Oblique sections of single or spermathecal caeca, and transverse sections of colleterial caecum (top, central section). Note the heavily staining granulated cytoplasm, epithelial cells and nuclei, pronounced development of endothelial nuclei, and chitinous inner lining, especially evident in the spermathecal caeca. The bottom section shows also the junction of the caecum and the reservoir, both containing some secretion. The development of an internal cleared zone is apparent in the colleterial caecum at the top. Photomicrograph. × 330.



a

b

PLATE 9

Longitudinal section of the pumping organ of the single or spermathecal gland. Note the oblique arrangement of the epithelium and localized thickening of the chitinous lining which gives the spiral lumen. The great development of both longitudinal and circular muscles is also apparent. Photomicrograph. × 333.

MACRORILEYA OECANTHI ASHM.

A HYMENOPTEROUS EGG PARASITE OF TREE CRICKETS

BY

LESLIE M. SMITH

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MACRORILEYA OECANTHI ASHM. A HYMENOPTEROUS EGG PARASITE OF TREE CRICKETS

BY

LESLIE M. SMITH

Macrorileya oecanthi Ashm. is an Eurytomid (Chalcidoidea) parasitic on the eggs of tree crickets (genus *Oecanthus*). The following paper includes data on its life-history, habits, and economic significance, which were collected by the author while studying the life-history and control of the snowy tree cricket, *Oecanthus niveus* DeGeer. The observations were largely made at San José, California, during 1927, 1928, and 1929. The life-history of this parasite is made especially interesting by the facts that the eggs of the parasite are deposited by the side of the host eggs, and that the larvae of the parasite tunnel along the canes in search of the eggs of *O. niveus*.

Ashmead (1904) using *oecanthi* as a type describes the genus as follows:

"FEMALES. Head and thorax smooth or nearly or, at the most, very finely punctate, or feebly microscopically shagreened. Antennae with three ring-joints. Pronotum quadrate, a little narrower than the mesonotum and hardly shorter than wide; parapsidal furrows distinct, complete; head transverse, as wide as the thorax across from tegula to tegula, subconcave behind, convex in front, with a frontal excavation for the antennal scape; flagellum subclavate, the funicle 6-jointed, joints 2–6 subquadrate, the last two a little wider than long; marginal vein very long, more than the stigmal vein, the postmarginal vein very long and slender; abdomen very long and narrow, lanceolate, subcompressed, nearly twice as long as the head and thorax united, joints 5, 6, and 7 long, the sixth the longest of the three, the eighth projecting and pointed.

"MALES. Antennae with three ring-joints. Head and thorax smooth or nearly, at most very finely punctate or microscopically shagreened, the parapsidal furrows sometimes delicate but distinct. Pronotum quadrate, nearly as long as wide and a little narrower than the mesonotum; abdomen elongate, cylindrical, as long as the head and thorax united, the segments subequal; flagellum subclavate, gradually thickened towards the tip, the last two joints of funicle transverse."

THE ADULT STADIUM

The adults (figs. 3, 4) are active yet, at the same time, clumsy insects, owing, no doubt to the greatly elongated abdomen, which is out of all proportion to the short legs and wings. The adults used for reinfesting the eggs of *Oecanthus niveus* DeGeer under laboratory conditions, and for other laboratory observations, were kept in flasks and fed honey and water separately. At first the honey and water were placed in drops on the sides of the flask, but the awkwardness of this species is so great that they soon became hopelessly caught in either honey or water. In order to overcome this difficulty, sheets of paper were sprayed with a mixture of honey and water, using a fine spray which produced very minute droplets on the paper. The paper was then cut in strips and a strip inserted in each flask. This procedure avoided the difficulty of entangling the insects in their food.

Both sexes fly well. Inasmuch as they are positively phototropic it was possible to make a few test flights in still air, by releasing them in the laboratory at a given distance from a window. In nearly all cases the specimens reached the window in a single flight. The greatest distance tested was sixteen feet. In view of these observations, it may be assumed that with favorable winds these parasites may have considerable distribution.

The adults have a very distinct resting position which is assumed only in cold, dark places. The head is normally carried in a transverse position, or slightly bent under the thorax, but at rest the lower part of the head is thrown forward and upward so that the face is on the same line as the dorsum of the thorax.

Mating occurs only in the sun on warm days. Numbers of specimens, males and females, were confined together but showed no interest in each other so long as they were in the shade. In the sun, however, mating occurred readily enough. In mating the male climbs to the back of the female, oriented as she is. Then he curls the tip of his abdomen under to the base of her abdomen. Immediately, he reverses his position and drops below the female. The male is of relatively small size, usually not longer than the abdomen of the female, and remains suspended from the lower side of her abdomen during copulation. The time required for mating varies from one to one and a half minutes.

Oviposition, likewise, occurs under the influence of sunlight. A flask, containing a number of males and females and raspberry canes with *O. niveus* eggs, was placed in the sun. Prior to being placed in the sun, no female attempted to oviposit. After being in the sun about twenty minutes, one female started to oviposit. Shortly, another began to oviposit on the same piece of cane. This cane was then gently lifted out with the two females on it and placed under a binocular. The two females remained on the cane for some time and laid a number of eggs, during which time the following procedure was observed. In oviposition, the female selects an egg puncture, after examining a number. The prospective location is first explored by the antennae, then by the palpi, which are thrown forward by the extension downward of the labium. The female then walks forward and attempts to insert the tip of the ovipositor in the egg puncture. In placing the tip of the ovipositor, the body is bent up in the middle with the wings held in line with the thorax and, consequently, away from the abdomen. If the ovipositor pierces the plug of chewed wood which protects the host egg, the female then walks backward, thus forcing the ovipositor down. When the ovipositor is fully inserted, the body is bent down in the middle. The evipositor remains fully inserted for from one and one-half to two minutes, then is withdrawn by walking forward. After resting a few minutes another host egg is attacked. No attempt is made to move to a new location or to find additional food for the larvae. In view of the larval habits, this is probably unfortunate from the standpoint of biological control, as will be shown later.

THE EGG

The evipositor of *M. oecanthi* is very long; it was estimated, that it must reach nearly to the bottom of the host egg. Consequently, a search was made by dissecting out eggs which had been marked as the females oviposited in them. No ovipositing scar could be found in the cap of the host egg, and, after some search, the egg of the parasite was found attached to the outside of the host egg (fig. 2). The parasite egg was always laid near the lower end of the host egg, the outer shell of which was often found to be broken, as though to aid the young larva in its attack upon its host.

The egg of *M. oecanthi* is roughly ellipsoidal, and about .23 mm. in length. At the upper end, the egg is continuous with a long filament

which extends the full length of the host egg. This filament is probably the collapsed receptacle which provided the means of transit for the egg, through the narrow channel of the ovipositor.

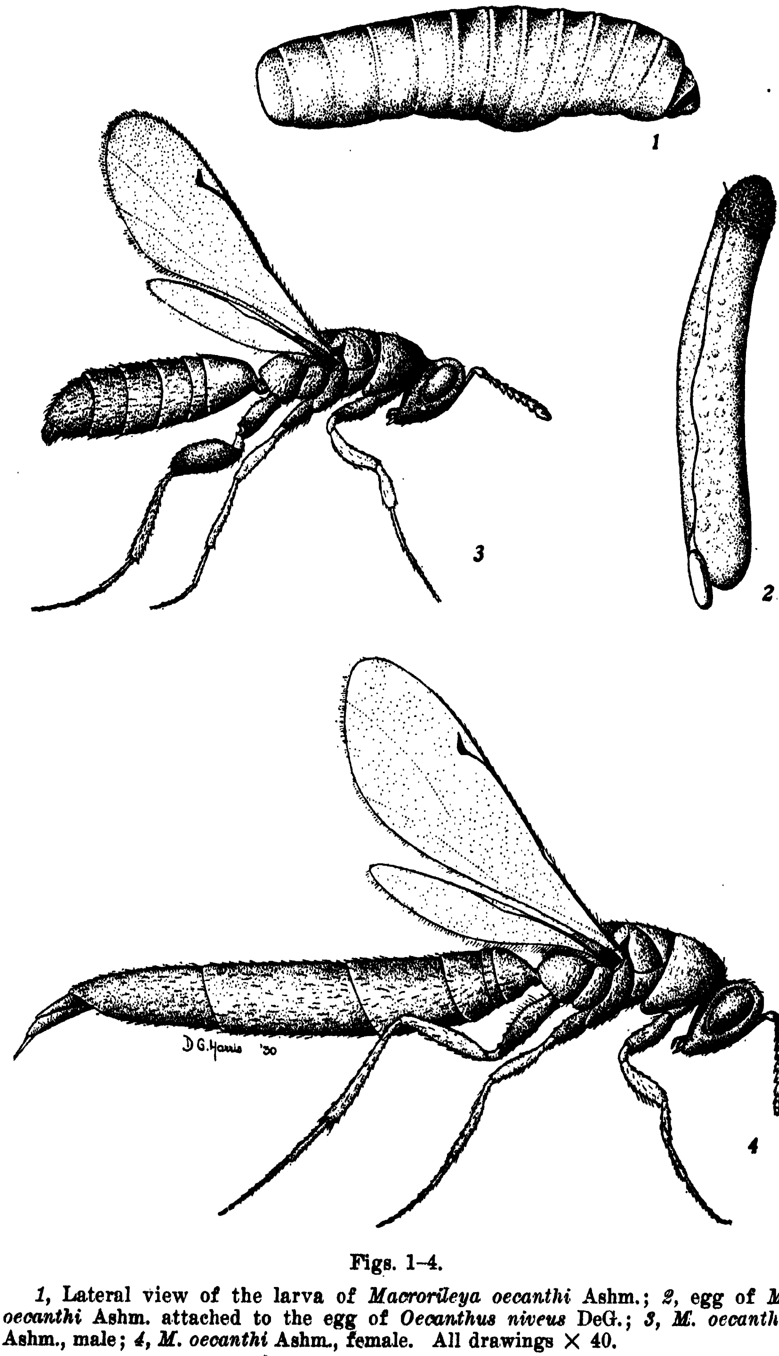
In the laboratory eggs were laid in the early part of October. In the field, however, the eggs may be laid at a considerably later period. The author was not able to observe oviposition in the field. The duration of the egg stage is likewise unknown. It must be relatively short, however, since eggs laid on September 7 had produced what appeared to be mature larvae by November 2, when these were dissected out.

THE LARVAL STADIUM

The larva is cylindrical, elongated, whitish, naked; having a distinct head with two minute, raised, pigmented spots on the front, somewhat resembling ocelli. The body is twelve-segmented, not counting the head. Ventrally, segments 4 to 7 show a pronounced bulging easily detected by the eye (fig. 1). The body ends bluntly in a truncated segment. The mouthparts are the only heavily chitinized part of the larva. They consist of a circum-oral ring supporting, dorsally, a three-pronged hook, the central prong being the shortest of the three. Inside of this ring are two fleshy protrusions apparently forming a sucker, with the mouth opening centrally between them.

The larvae are very sluggish in their movements and even when violently stimulated, as by contact with acids or by heat, their movement can be detected only by close observation. Dorsally and ventrally on segments 4 to 7 distinct dimples, are located, evidently used in the same manner as are the sucking discs of the Cerambycids. The bulging of the larvae in this region probably is an additional aid in grasping the sides of the burrow. The flat disc at the end of the body, formed by the truncation of segment twelve, can likewise be strongly invaginated and no doubt functions as a sucker. The fleshy lobes, previously mentioned, which lie above and below the mouth, although resembling a sucker in structure have never been seen to exhibit the least movement.

Attempts were made to rear larvae in petri dishes, after removing them from the canes, but in no case did a larva so placed succeed in puncturing an egg. In fact, their movements are so slow that it is impossible to observe any reaction, either positive or negative, when the larva is placed in contact with a host egg.



Figs. 1–4.

1, Lateral view of the larva of *Macrorileya oecanthi* Ashm.; *2*, egg of *M. oecanthi* Ashm. attached to the egg of *Oecanthus niveus* DeG.; *3*, *M. oecanthi*, Ashm., male; *4*, *M. oecanthi* Ashm., female. All drawings × 40.

However, a number of larvae were dissected from canes and upon these the following study of habits is based. After hatching, the young larva probably first consumes the egg upon which it finds itself. This operation is probably very rapid, for the host eggs, once punctured, are quick to mold or decay. The larva then begins burrowing through the pith channel of the cane until it encounters another egg of *niveus*, which it eats; then the larva continues to burrow along the stem to the next egg. The number of eggs consumed in this way, or injured in passing, so that molds get in, varies from ten to fifteen for each larva.

The burrows constructed by the larvae are smooth and generally free from frass. Except where the larva consumes an egg, the burrow is probably constructed by compressing and packing the pith rather than by tearing pieces of it free. The burrows wind at random along the stem and rarely if ever double back on themselves. The length depends entirely upon the food supply. If the host eggs are closely placed, the burrow is short, if they are widely spaced the burrow is long. One burrow was observed which measured fifteen inches. It is peculiar that whenever a larva is found at the end of a burrow, it is usually headed in the opposite direction to that in which it must be traveling. This seems to indicate that the larvae travel backward, using the posterior sucker for compacting the pith as they advance. To test this, artificial holes were made in pieces of canes and in two cases larvae were placed in head first, and in a third, tail first. At the end of twenty-four hours, the two larvae placed in head first had backed out of their artificial burrows, while the one placed in tail first remained at the bottom of the hole, but had not tunneled farther. These results are too preliminary to enable one to state definitely that the larvae travel backward, but, so far, all indications are that such is the case.

The larvae do not completely rid a section of the stem of eggs, but usually miss two or three in the entire feeding period. This, together with the winding character of the burrow, would indicate that the larvae are not capable of sensing the eggs, but come upon them by chance. Probably hunger is a stimulus to burrowing in this case.

The larvae are believed to be cannibalistic since, whenever two are in the same burrow, they construct a compact plug of pith between them. Apparently, larvae commonly follow down the burrows of other larvae, for three larvae were once found in the same burrow, each separated from the rest by pith plugs. The middle one was thus a helpless prisoner. These tendencies and the female's habit of

remaining in the same general locality while ovipositing, may greatly reduce the control which this species might otherwise exercise upon its host.

The length of the larval period could not be determined, but probably covers about ten months. Larvae pupated successfully in petri dishes, after being removed from the stem. Pupation occurred in the laboratory during the early part of July, and, as was previously pointed out, large larvae were obtained in the first part of November.

THE PUPAL STADIUM

The pupa exhibits the usual characters of Hymenopterous pupae and resembles the adult in sufficient characters to be distinguished readily. The very long, pointed, abdomen and very short wing pads of the female render the pupa easily recognizable.

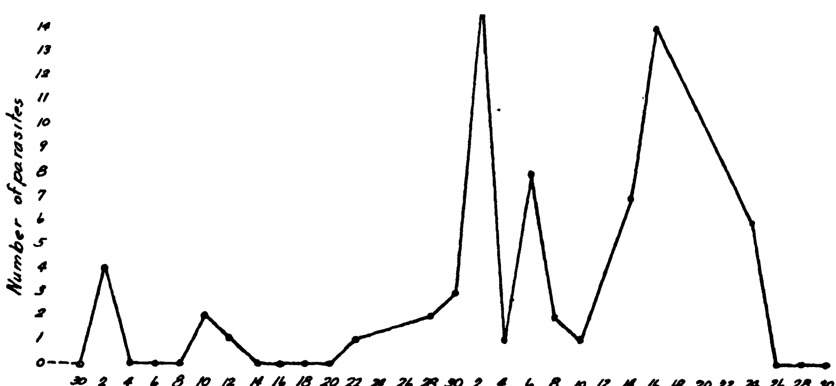


Fig. 5.

The pupa lies at the end of the burrow, usually, and is protected by a plug of pith in the open end of the burrow, thus making a distinct pupal cell. The pupae are incapable of movement. As has been said before, mature larvae pupate when lying free in a petri dish, and from pupae so obtained the pupal period was determined, under laboratory conditions. This period varied from 13 to 18 days, the emergences occurring during the latter part of July. Figure 1 shows the numbers of parasites which emerged on various days for the entire period of emergence from a single bundle of canes. These canes were kept out of doors through the winter, then removed to the laboratory about the middle of May. Where counts were made on odd-numbered days these were added to the following even-numbered days.

HOSTS AND HYPERPARASITES

The writer has reared *M. oecanthi* Ashm. from eggs of *Oecanthus niveus* DeG., and *O. californicus* Sauss. It seems likely that *M. oecanthi* will attack the eggs of any tree cricket, that may be accessible to it.

One species, an unidentified Peteromalid, was found to be parasitic upon the larvae of *M. oecanthi*. This hyperparasite was found as a minute larva, attached to the larva of *M. oecanthi*. Two larva of the hyperparasite were found and one was reared to maturity. Both larvae completely devoured their host, leaving only part of the skin and the mouthparts.

LITERATURE CITED

Ashmead, W.

1904. Classification of the chalcid flies, or the superfamily Chalcidoidea. Mem. Carn. Mus., Pittsburgh, 1:225–551.

THE CALIFORNIA SPECIES OF THE GENUS AMITERMES SILVESTRI (ISOPTERA)

BY

S. F. LIGHT

The large tropicopolitan genus *Amitermes* Silvestri (Family Termitidae, Order Isoptera) includes species with a very wide range of habits and habitats. A number of species of the genus range into southwestern United States, particularly into Texas, New Mexico, Arizona, and southern California. Here they are confined in large part to the desert or semi-desert arid regions and form a characteristic element of the faunas of such areas. For this reason I have designated them the Desert Termites (1929).

These termites present numerous fascinating problems. Their life-histories, habits, and ecology are practically unknown. That they may become of economic importance we know from the attacks of *Amitermes wheeleri* Desneux on wooden structures (Banks and Snyder, 1920) and of *Amitermes arizonensis* Banks on young citrus trees (see below). Why is the desert especially favorable for them? What limits their distribution in it? How do organisms so delicate and easily desiccated as these preserve a sufficient moisture content within their galleries? How do they build their galleries? Why are some species able to eat only the outer, weathered wood while others attack the sound wood, or is this a mere matter of preference? How, in the absence of xylophagous Protozoa, are they able to digest cellulose? Do they produce a cellulase? Are they by any chance fungus growers? Do they depend upon cellulose-splitting Protista? How large are the colonies? How, where, and when are the colonies founded? How rapidly do they develop? What is the location of the royal pair and to what extent does the queen undergo physogastry? To what extent and under what conditions may we expect some or all of these species to become of economic importance? These are only a few of the many interesting problems presented by these Nearctic intruders from the Neotropical Region.

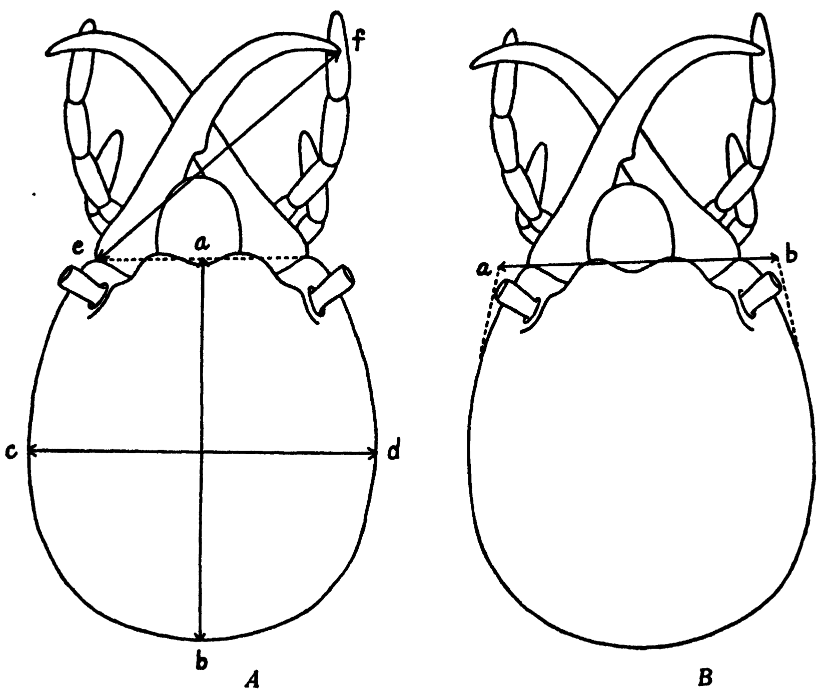
Previous to the initiation of the field program of the Termite Investigations Committee in 1928, but two species of *Amitermes* had been reported from California (Banks and Snyder, 1920); *Amitermes arizonensis* Banks, from Arrowhead Springs, San Bernardino County (Snyder), and Palm Springs, Riverside County (Hubbard); and *Amitermes californicus* Banks from Jacumba, San Diego County (F. P. Keen), Arrowhead Springs, San Bernardino County (Snyder), and Coyote Wash, Imperial County (W. D. Pierce). The field investigations of Mr. A. L. Pickens, one of the field biologists of the Committee, and those of the present author, together with the recent collections of Mr. G. B. Castle and Mr. O. L. Williams of the Termite Investigations Committee, and single collections by others as noted in the discussions of distribution for the separate species, have given us a fair preliminary knowledge of the identity of the species found in the State, and their distribution. These collections have increased the number of species known from the State to seven species of which four species are new to science, as follows:

Amitermes arizonensis Banks
Amitermes californicus Banks
Amitermes emersoni new species
Amitermes silvestrianus new species
Amitermes snyderi new species
Amitermes wheeleri Desneux
Amitermes coachellae new species

Three of the new species have been named respectively for Dr. Alfred E. Emerson, Associate Professor of Zoology in the University of Chicago, Dr. Filippo Silvestri, Director of the Laboratory of Zoology, College of Agriculture, Portici, and Dr. Thomas E. Snyder, Senior Entomologist of the United States Bureau of Entomology, each of whom has made notable contributions to the taxonomy and biology of termites. It is a pleasure to be able thus further to imbed these names in the nomenclature of the group. The fourth new species is named for the Coachella Valley where this remarkable fauna has been found.

The maps accompanying the discussions of the individual species give the distribution as at present known. The dots represent localities in which one or more collections have been made. That much remains to be done before our knowledge of these species is in anything approaching a satisfactory state is indicated by the fact that no alates or reproductives of any sort have been reported from the State, and that the alates of the new species are as yet unknown. There is also much confusion as to the identity of alates of the other species.

The key to the soldiers given below is purely artificial but should make possible ready determination of all the species for which the soldiers are known. Because of our very incomplete knowledge of the alates they have been ignored at this time. *Amitermes tubiformans* Buckley is the only North American species of the genus whose soldiers are known but which has not yet been found in southeastern Cali-



Figs. A and B. Head of soldier of *Amitermes tubiformans* Buckley in dorsal view, illustrating measurements used.

Fig. A. The lines *ab*, *cd*, and *ef* show, respectively, how head length, head width, and mandible length are measured.

Fig. B. The line *ab* shows how minimum head width is measured.

fornia. I have included it in the key in order to make this available for use in other parts of the United States. Some measurements and indices for this species are given to permit comparisons.

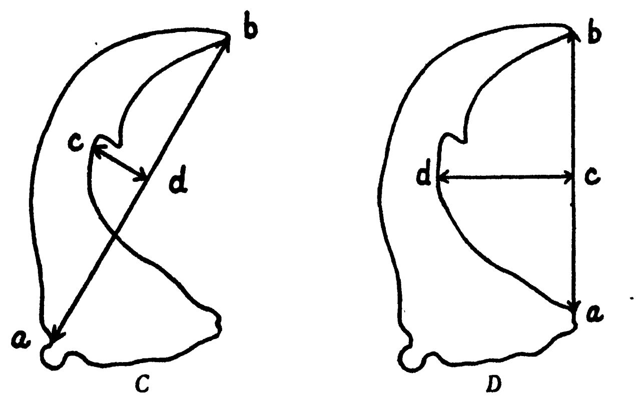
It is believed that soldiers may be identified in the field with the aid of a hand lens. Worker identifications will present greater difficulties since satisfactory distinguishing characters have yet to be defined.

Mr. Pickens has made many of the observations given under the brief discussions of the biology of the various species. Several other collaborators have had to do with formulating the data here presented.

Mr. G. B. Castle, in charge of collections for the Termite Investigations Committee, has prepared the distribution data; Miss Frances Sharman performed the arduous task of making the measurements on the workers of all save *Amitermes emersoni* new species, and my research assistant, Miss Ethel Craig, has made many measurements, prepared the illustrations, and in many ways aided the preparation of the manuscript.

Use of Terms—

The terms used to designate dimensions, and the indices, both of which appear in the diagnoses and descriptions of species, are defined below and briefly discussed.



Figs. C and D. Left mandible of soldier of *Amitermes snyderi* new species, illustrating measurements.

Fig. C. The lines *ab* and *cd* show, respectively, how mandible length and minimum mandible curvature are measured.

Fig. D. The lines *ab* and *cd* show, respectively, how inner mandible length and mandible curvature are measured.

Head length, unless otherwise qualified, refers to the length of the head capsule. It is measured, as indicated by figure A (*ab*) from the middle of the posterior margin to a line joining the anterior margins of the head capsule. For the workers there is given in addition, head length to the clypeal suture (bb′ in fig. E).

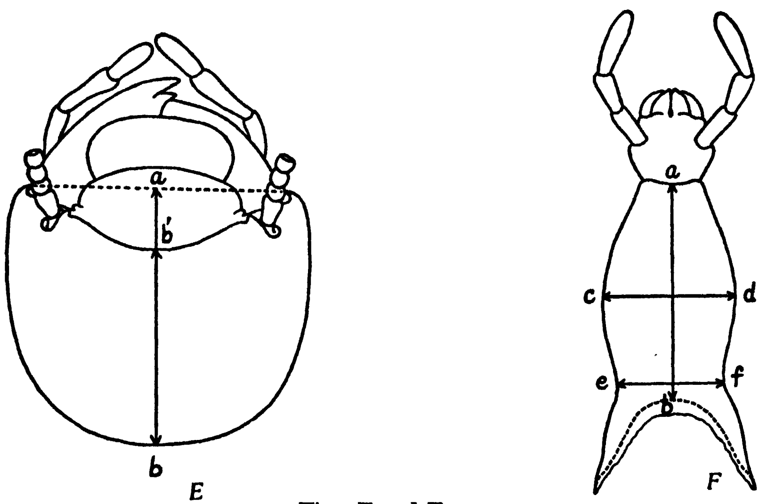
Head width is measured at the widest point (fig. A, *cd*).

Minimum head width is a dimension necessary in order to arrive at a value to represent the degree of anterior contraction of the head, the head contraction index, discussed below. As will be seen from figure B (*ab*), this is not a real dimension but the width which the head capsule would have at its extreme anterior end if the accessory contraction

resulting from the insertion of the antennae and the rounding in of the antero-lateral margins are eliminated.

Mandible length is the length of the left mandible of the soldier measured from the notch at the base of the outer mandibular condyle to the tip of the mandible (fig. A, *ef;* fig. C, *ab*). This definition of mandible length is chosen because it allows for measurement of this dimension without dissection.

Inner mandible length is measured in a straight line from the inner point of the basal projection of the left mandible to the tip of the mandible (fig. D, *ab*). It is desired in order to arrive at a value to express mandible curvature in the mandible curvature index I discussed below. In this genus it is a hybrid dimension varying with (1) length of mandible, (2) curvature of mandible, and (3) size and shape of the basal projection. This dimension was used by Emerson (1928) in deriving "mandible curvature," as defined below, for the soldiers of *Mirotermes* (*Cubitermes*).



Figs. E and F.

Fig. E. Diagrammatic dorsal view of head of worker of *Amitermes arizonensis* Banks to show how head length (*ab*) and head length to clypeal suture (*bb'*) are measured.

Fig. F. Diagrammatic ventral view of gula of soldier of *Amitermes snyderi* new species to show how gular length (*ab*), maximum gular breadth (*cd*), and minimum gular breadth (*ef*) are measured.

Mandible curvature (*cd* in fig. D), "a measurement which is taken by placing the left mandible in a natural position on a plane surface, then measuring with a micrometer the distance between an imaginary base line, running from the tip of the mandible to the basal projection,

and the edge of the mandible at the point of greatest curvature" (Emerson, 1928).

Minimum mandible curvature (*cd* in fig. C) is a designation which I have used for want of a better term for the greatest distance, measured at right angles, between the base line made in measuring mandible length (*ab* in fig. C), and the inner margin of the mandible with the mandible lying on a plane surface. This was used in seeking a means of eliminating certain of the variable factors in the derivation of mandible curvature index I, the resulting value being termed mandible curvature index II.

Gular length (*ab* in fig. F) is measured from the middle of the labial suture to the middle of the *inner* posterior margin of the gula (gulamentum), represented by the dotted line in figure F. This is shorter than the actual observed external length of the sclerite but is used to avoid the difficulty found in determining the exact posterior limits of the sclerite if the outer margin is used.

Maximum gular breadth (*cd* in fig. F) is measured at the widest point in the distal one-half of the sclerite.

Minimum gular breadth (*ef* in fig. F) is measured at the point of greatest contraction in the proximal one-half of the sclerite. It is ordinarily less than the preceding measurement but where the contraction is slight or lacking it may even exceed it, as in *A. arizonensis* (pl. 13, fig. 7).

Pronotum width is measured at the widest point.

Indices or ratios of proportion have been used in an effort to place these characters in readily usable form (Light, 1927). These indices have been derived so as to make them, save in rare cases, fractions of unity, thus making them readily comparable. *Head index,* a measure of relative breadth of head, is obtained by dividing maximum head breadth by head length, *head contraction index* by dividing minimum head breadth by maximum head breadth, *head mandible index* by dividing mandible length by head length, and *gular contraction index* by dividing minimum gular width by maximum gular width. *Mandible curvature index I* is obtained by dividing mandible curvature by inner mandible length. *Mandible curvature index II* is obtained by dividing minimum mandible curvature by mandible length. Table I shows the results of these two attempts to express mandible curvature by means of indices.

TABLE 1

CALIFORNIA *Amitermes* SPECIES ARRANGED ON THE BASIS OF MANDIBLE CURVATURE INDICES I AND II OF THE SOLDIER AS DERIVED FROM MEASUREMENTS MADE ON THE MANDIBLES FIGURED IN PLATES 12 AND 14

Species	Mand. Curv. Index II	Mand. Curv. Index I
A. arizonensis Banks	0.03	0.11
A. emersoni new species	0.08	0.25
A. silvestrianus new species	0.11	....
A. californicus Banks	0.12	0.42
A. coachellae new species	0.14	0.33
A. snyderi new species	0.16	0.43

A comparison of the order of increasing curvature by means of mandible curvature index II with the observed degree of curvature, as brought out in photographs of the mandibles (pl. 12, figs. 6–10; pl. 14, figs. 8, 9), would seem to indicate this as the more accurate of the two indices. It at least eliminates the factor of variation in length and depth of the basal projection, which enters into mandible curvature index I. It will be seen that the discrepancy which arises in using mandible curvature index I is readily explained in the relatively wider and higher basal projection of *A. californicus* (pl. 12, fig. 6), which emphasizes mandible curvature and reduces inner mandible length and hence gives an abnormally high curvature index. While these indices must be applied to many more species before their general applicability can be ascertained, it seems probable that mandible curvature index II will give the more real indication of curvature of the mandible in groups where the curvature is at all prominent. Very slight curvatures could not be expressed by this value since there would be no minimum mandible curvature.

PHYLOGENETIC GROUPINGS

These eight species of *Amitermes* found on the borders of the Nearctic region are remarkably distinct as termite species go, even leaving out of consideration characters of alates, which may be expected still further to separate them. This would seem to suggest great age as species in spite of their present seemingly similar habitats. It may probably mean that they represent surviving remnants of larger species groups fitted to special differing ecological niches not as yet understood.

There are indications of phylogenetic affinities within the group, however, even in the absence of the alate characters, which will no doubt shed much light on this point. The shape and length of mandible, the nature and location of the teeth, and the shape of the gula seem to afford the most definite indications of relationships. The five groups which seem to be indicated are as follows:

1. The *tubiformans* group
   - *A. tubiformans* Buckley
   - *A. arizonensis* Banks
8. The *wheeleri* group
   - *A. wheeleri* Desneux
   - *A. coachellae* new species
3. The *snyderi* group
   - *A. snyderi* new species
4. The *emersoni* group
   - *A. emersoni* new species
   - *A. silvestrianus* new species
5. The *californicus* group
   - *A. californicus* new species

The affinities of these five groups are much in doubt and further light must be sought from the much to be desired studies on the winged caste.

KEY TO THE SOLDIERS OF THE CALIFORNIA SPECIES OF *AMITERMES*

1. Mandibles as long as or nearly as long as head, nearly straight save at tip; antennae brown to black in distal half 2
   Mandibles shorter than head, distinctly curved; antennae yellow throughout 3
2. Mandibles not so long as head, bent from near middle, teeth near middle of mandibles .... *A. tubiformans* Buckley (fig. A)
   Mandibles about as long as head or longer, curved only near tip, tooth distinctly below middle .... *A. arizonensis* Banks (pl. 11, fig. 5)
3. Teeth in middle of mandibles or beyond 4
   Teeth in proximal half of mandibles 6
4. Mandibles massive, rough, strongly curved, mandible curvature index II, 0.16 .... *A. snyderi* new species (pl. 11, fig. 4)
   Mandibles slender, smooth, less curved, mandible curvature index II, less than 0. 12 5
5. Teeth in distal third of mandibles........ *A. emersoni* new species (pl 11, fig. 2)
   Teeth near center of mandibles........ *A. silvestrianus* new species (pl. 14, fig. 8)
6. Mandibles very short, massive, dark red; teeth massive, cone-shaped, projecting........ *A. californicus* Banks (pl. 11, fig. 1)
   Mandibles longer, thin; teeth small, hardly projecting 7
7. Smaller, head less than one millimeter wide: "head high"; mandibles slender beyond teeth .... *A. wheeleri* Desneux (fig. AA)
   Larger, head more than one millimeter wide: " head lower"; mandibles broad beyond teeth .... *A. coachellae* new species (pl. 14, fig. 1)

Amitermes arizonensis Banks

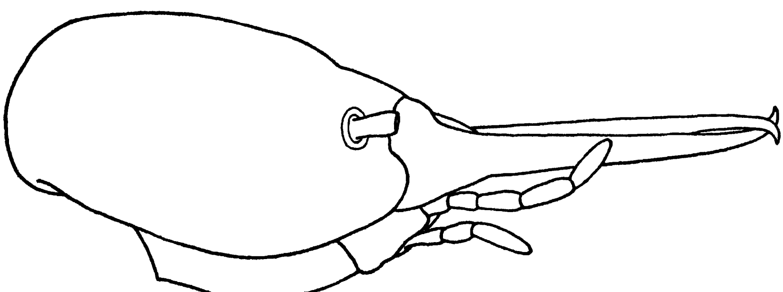
Arizona termite (Essig); Arizona desert termite (Light)

Plate 10; plate 11, figure 5; plate 12, figures 5 and 10; plate 13, figures 6 and 7; figures G–J

Amitermes californicus Banks 1920, U. S. Nat. Museum, Bull. 108.

DIAGNOSES

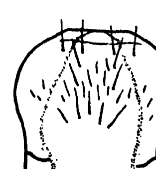
Soldier. Large, with light-colored swollen abdomen; head capsule (pl. 11, fig. 5) short, nearly rectangular in dorsal view; about 1.15 mm. wide and 1.27 long; head index about 0.9; head broadest behind middle, sides slightly convex, converging anteriorly; head contraction index about 0.95. Mandibles nearly straight save at tips, slender, as long as head (fig. G); head-mandible index about 1.0; teeth low, incon-



G

H

I



J

Figs. G–J. *Amitermes arizonensis* Banks. All figures are camera lucida outlines. × 40.

Fig. G. Head of soldier in lateral view.
Fig. H. Labrum of soldier in dorsal view.
Fig. I. Pronotum of soldier in dorsal view.
Fig. J. Labrum of worker in dorsal view.

spicuous, in basal half of mandibles (pl. 12, fig. 10); left tooth low, slightly more distal than right and fitting into notch just in front of right tooth; right tooth pointed, projecting; mandibles somewhat constricted just proximal to teeth; basal projections relatively slight; mandible curvature slight, mandible curvature index I about 0.11; mandible curvature index II about 0.03. Gula (pl. 13, fig. 7) expanding posteriorly, broadest near posterior end, with a very slight contraction posterior to middle; gular contraction index about 1.05. Distal half of antennae brown (pl. 11, fig. 5).

Worker. Seemingly of two types, light-headed (perhaps nymphs of soldiers) and yellow-headed. Yellow-headed types considered to be definite workers. Head capsule rather rectangular, parallel-sided in anterior one-half (pl. 13, fig. 6); head more than 1 mm. in width; distal half of antennae brown; two outer teeth of each mandible (pl. 12, fig. 5) long, sharp, with deep narrow cleft between them.

Measurements in Millimeters, and Indices, of Soldiers of *Amitermes arizonensis* Banks

	Maximum	Minimum	Average	Number measured
Head length	1.36	1.19	1.27	5
Maximum head width	1.19	1.12	1.15	5
Head width between antero-lateral corners	.96	.91	.94	5
Minimum head width	1.12	1.07	1.09	5
Mandible length	1.39	1.19	1.30	5
Gular length	.70	.62	.65	5
Maximum gular breadth	.33	.31	.32	5
Minimum gular breadth	.36	.33	.34	5
Pronotum width	.84	.79	.82	5
Labrum length	.36	....	....	1
Labrum width	.29	....	....	1
Head index	.94	.88	.91	5
Head contraction index	.99	.90	.95	5
Head-mandible index	1.00	.98	.99	3
Gular contraction index	1.10	1.00	1.04	5
Inner mandible length	1.26	....	....	1
Mandible curvature	.14	....	....	1
Mandible curvature index I	.11	....	....	1
Mandible length used in deriving mandible curvature index II	1.39	....	....	1
Minimum mandible curvature	.04	....	....	1
Mandible curvature index II	.03	....	....	1

Measurements in Millimeters of Workers of *Amitermes arizonensis* Banks

	Maximum	Minimum	Average	Number measured
Head length	1.06	.97	1.02	5
Head length to clypeus	.89	.71	.79	25
Head width	1.21	1.00	1.10	25
Distance between mandibular articulations	.52	.46	.49	25
Clypeus length	.29	.20	.27	25
Antenna length	1.53	1.18	1.37	25
Mandible length	.57	.39	.50	25
Pronotum length	.35	.21	.30	25
Pronotum width	.72	.57	.65	25
Thorax length	1.06	.59	.72	25
Thorax width	.94	.65	.76	25
Abdomen length	2.54	1.71	2.06	25
Abdomen width	1.53	.94	1.18	25

Distribution.—This species was reported by Banks and Snyder (1920) from two localities in California, Arrowhead Springs near San Bernardino (Snyder), and Palm Springs (Snyder), and from several localities in southern Arizona. My collections in Arizona and southeastern California and those of Pickens in California show this to be our commonest species of Amitermes. In Arizona I have taken it at Topac (just across the Colorado River, from Needles, California), near Casa Grande, in Florence, and in Sabino Canyon near Tucson. A collection by Mr. A. W. Keller, who has made a number of important collections in Arizona, from a point 71 miles north of Phoenix, extends materially its known northern range in Arizona. In California, as the

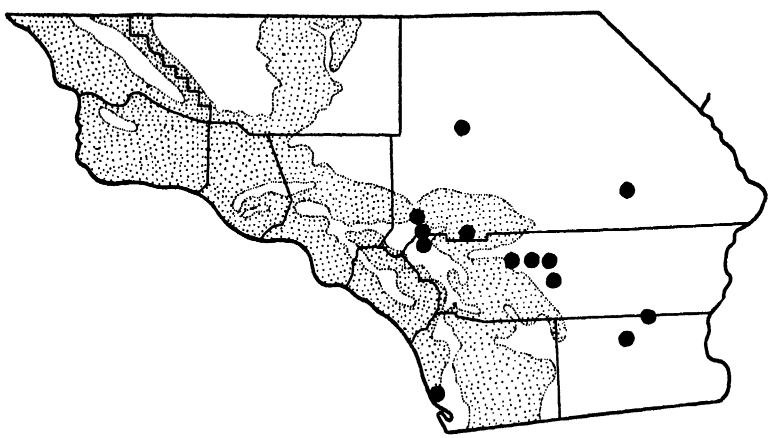


Fig. K. Map of the southern counties of California showing distribution of *Amitermes arizonensis* Banks. The white area represents the lower Sonoran life zone and the dotted area the other life-zones as defined by Grinnell (1915).

map (fig. K) shows, it is common to the Colorado and Mojave deserts and spills over the mountain barriers, having been taken at Riverside, Redlands, and Arrowhead Springs near San Bernardino and at La Jolla. The La Jolla record is based on a collection recently received from Professor W. E. Allen, of the Scripps Institution. Dr. Ralph H. Smith, Associate Entomologist of the Citrus Experiment Station at Riverside, has sent me collections from Riverside and Yucaipa.

Biology.—Travelers in the desert regions of California and Arizona are often puzzled by finding worm-like earthen tubes in large numbers and in bizarre arrangement. These are the shelter tubes built by *Amitermes arizonensis* (pl. 10) over dead desert vegetation which it often eats entirely away, leaving the tubes duplicating each bend,

excrescence, and branch of the plant over which they were originally made. This termite is not known to enter wood but often builds broad sand or clay shelters over posts from which it eats only the paper-thin, outer, weathered layer. These shelters have been seen covering the whole surface of a pole for as high as twenty feet above the ground.

While not known to be destructive to wooden structures, this termite has been reported (*in lit.*) by Dr. Ralph H. Smith as attacking young grapefruit trees, apparently first attacking the burlap of the "ball" and going from this to the living tree. About one in a hundred trees were killed in the case reported. Cases of supposed damage by this species to palm trees have proved so far to be erroneous, although this termite commonly builds its covered way over the dead leaf stalks and the trunk. This has been noted, particularly in Redlands, but it occurs, no doubt in other localities.

Amitermes californicus Banks

California termite (Essig); California desert termite (Light)

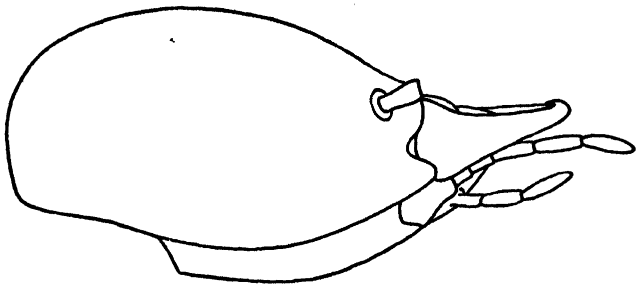
Plate 11, figure 1; plate 12, figures 1 and 6; plate 13, figures 1 and 5; figures L–O

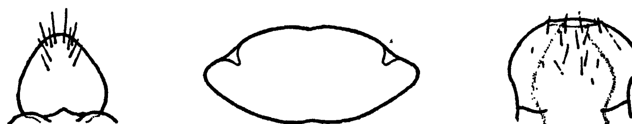
Amitermes californicus Banks 1920, U. S. Nat. Museum, Bull. 108.

DIAGNOSES

SOLDIER. Small, abdomen usually gray, elongated. Head capsule (pl. 11, fig. 1) long; about 1.12 mm. wide and 1.36 mm. long; head index about 0.82; sides of head nearly straight, converging slightly from near posterior end; head contraction index about 0.95; mandibles (pl. 12, fig. 6) short; massive, dark red; mandibles less than one-half as long as head; head-mandible index about 0.46; mandibles strongly curved, mandible curvature index I about 0.42, II about 0.12; tooth large, conical, not shelf-like, projecting inward. Gula (pl. 13, fig. 5) broadest near anterior end, distinctly contracted posteriorly, narrowest near posterior end; gular contraction index about 0.73. Antennae yellow, shorter than head.

WORKER. Body elongated, grayish in color. Head capsule (pl. 13, fig. 1) short and broad, rounded posteriorly, sides parallel anteriorly with squarely rounded antero-lateral corners; head about 0.93 mm. in width; antennae light-colored throughout; mandibles (pl. 12, fig. 1) with short blunt teeth; basal projection of left mandible broad and strongly convex posteriorly; basal projection of right mandible shorter than distance between it and base of second tooth.





Figs. L–O.

Amitermes californicus Banks. All figures camera lucidia outlines. × 40.

Fig. L. Head of soldier in lateral view.
Fig. M. Labrum of soldier in dorsal view.
Fig. N. Pronotum of soldier in dorsal view.
Fig. O. Labrum of worker in dorsal view.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIERS OF *Amitermes californicus* BANKS

	Maximum	Minimum	Average	Number measured
Head length	1.42	1.33	1.36	5
Maximum head width	1.15	1.04	1.12	5
Head width between antero-lateral corners	.88	.81	.86	5
Minimum head width	1.04	.96	1.01	3
Mandible length	.68	.65	.66	5
Gular length	.73	.70	.72	4
Maximum gular breadth	.34	.31	.33	5
Minimum gular breadth	.26	.20	.24	5
Pronotum width	.75	.64	.70	5
Labrum length	.29	.....	.....	1
Labrum width	.28	.....	.....	1
Head index	.87	.78	.82	5
Head contraction index	.96	.93	.95	3
Head-mandible index	.48	.45	.....	2
Gular contraction index	.80	.62	.73	5
Inner mandible length	.48	.....	.....	1
Mandible curvature	.20	.....	.....	1
Mandible curvature index I	.42	.....	.....	1
Mandible length used in deriving mandible index II	.68	.....	.....	1
Minimum mandible curvature	.08	.....	.....	1
Mandible curvature index II	.12	.....	.....	1

MEASUREMENTS IN MILLIMETERS OF WORKERS OF *Amitermes californicus* BANKS

	Maximum	Minimum	Average	Number measured
Head length to clypeus	.71	.65	.69	9
True head length	.90	.87	.89	5
Head width	.94	.89	.93	9
Distance between mandible articulations	.45	.42	.44	9
Clypeus length	.22	.19	.21	9
Antenna length	1.24	1.00	1.15	9
Mandible length	.46	.37	.41	9
Pronotum length	.31	.24	.28	9
Pronotum width	.55	.48	.53	9
Thorax length	.77	.60	.65	9
Thorax width	.77	.59	.67	9
Abdomen length	2.36	2.00	2.20	9
Abdomen width	1.48	.94	1.17	9

Distribution.—This species, described by Banks (1920), was reported by him from but three localities, two in California—Jacumba, San Diego County (Keen) and Arrowhead Springs, near San Bernardino (Snyder), the third locality, Sabino Canyon, Arizona (Hofer).

I found it common at the mouth of Sabino Canyon, and a collection by A. W. Keller from Casterline Cabin some distance north of Phoenix adds considerably to the northern range of the species in Arizona.

The collections of the Termite Investigations Committee and single collections by Mr. Walter Putnam and Mr. A. C. Davis show this species to have the widest range in California of any species of *Amitermes* (fig. P). It occupies both the Colorado and Mohave deserts

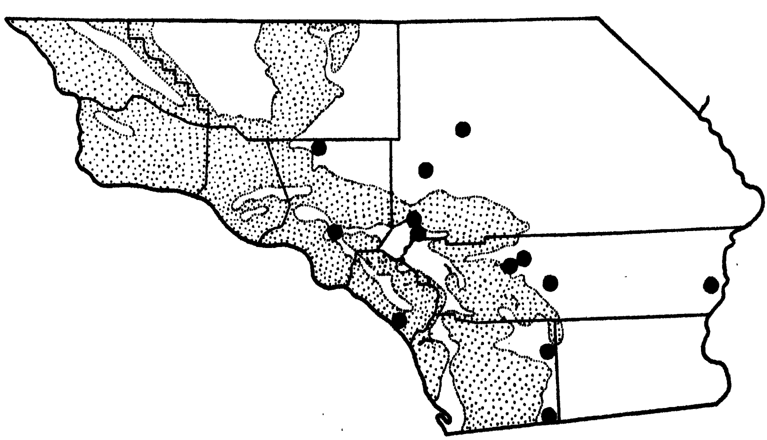


Fig. P. Map of the southern counties of California to show distribution of *Amitermes californicus* Banks. The white area represents the lower Sonoran life zone and the dotted area the other life-zones as defined by Grinnell (1915.

and extends to the coast in Orange County (Putnam) and as far north as Fairmont in Los Angeles County (Davis). It is most abundant in the Joshua tree forest on the eastern slope of Cajon Pass where it infests the butts of dead flower stalks of *Agave*.

Biology.—This species, while not known to make serious attacks on wood, is quite capable of eating it and has been found eating stakes and pieces of wood on or in the ground as well as attacking dead stumps and stubs. Its most favored location is the base of dead flower stalks of *Agave* where large colonies including nymphs with large wing pads were found in early September by Emerson, Snyder, Pickens, Harvey, and myself in the upper reaches of the Joshua tree forest on the eastern slope of Cajon Pass. (See also Snyder, 1920, for a discussion of the biology of this species.)

Amitermes emersoni new species

Emerson's desert termite

Plate 11, figure 2; plate 12, figures 2 and 7; plate 13, figures 2 and 8; plate 14, figure 7; figures Q–U

DIAGNOSES

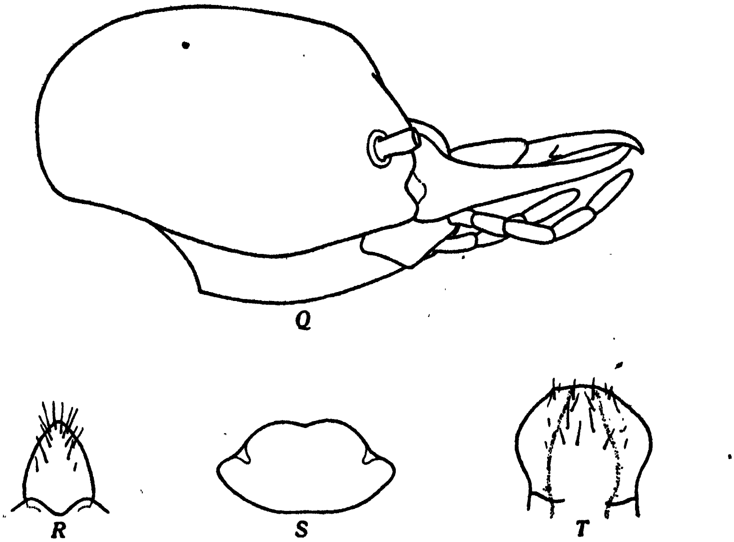
ALATE. Unknown.

SOLDIER. Small, head capsule about 0.99 mm. wide and 1.12 mm. long. Head broadest near posterior end, sides convex, converging anteriorly; head index about 0.88; head contraction index about 0.77. Mandibles slender, light-colored, not strongly curved; basal projection not large; mandible curvature index I about 0.25, II about 0.08; mandibles fairly long, head-mandible index about 0.72; teeth in outer third of mandibles, sharp, directed toward base of mandible. Gula broad, broadest near posterior end, broadly but shallowly contracted near middle; gular contraction index about 0.95. Antennae somewhat longer than head, pale yellow-brown.

WORKER. Head averaging 0.95 mm. in width and 1.12 mm. in length, shaped as in figure 2 of plate 13. Mandibles with blunt teeth; basal projection of right mandible longer than distance between it and base of second tooth; basal projection of left mandible pointed, its proximal surface not convex.

DESCRIPTIONS

SOLDIER. Head and antennae yellow, mandibles light yellow at base deepening to light yellow-brown distally; legs and ventral areas of thorax and abdomen white, dorsal surfaces of thorax and abdomen with yellowish tinge; abdomen with dark appearance due to dark material in intestine. Abdomen not greatly swollen, more or less cylindrical, blunt posteriorly.



Figs. Q–T.

Amitermes emersoni new species. All figures camera lucida outlines. × 40.

Fig. Q. Head of soldier in lateral view.
Fig. R. Labrum of soldier in dorsal view.
Fig. S. Pronotum of soldier in dorsal view.
Fig. T. Labrum of worker in dorsal view.

Head (pl. 11, fig. 2) broad, broadest near posterior margin, sides somewhat convex, posterior border nearly straight, postero-lateral corners broadly rounded, sides converging from near posterior end, head index about 0.88, head contraction index about 0.77; head high with steep, curved, posterior and lateral sides, and steep, truncated frons; fontanel protuberance slight; marked by dense group of light reddish hairs of various sizes.

Mandibles as in figure 7 of plate 12; narrow in dorsal view, about half as thick as broad; directed somewhat upward from the bases, weakly incurved from near middle; basal projection small, low; mandible curvature index I, 0.25, II, 0.09; mandibles not as long as head; head mandible index about 0.76; teeth in outer one-third, sharp, shelf-like, directed basally, projecting inwardly but little. Antennae (pl. 11, fig. 2) longer than head, of fourteen segments, IV shortest, III to V together twice as long as II.

Labrum as in figure R.

Gula (pl. 13, fig. 8) broad in proportion to length, contracted behind middle, gular contraction index about 0.95.

Pronotum as in figure S.

WORKER. Small, head not more than 1 mm. wide; abdomen not greatly swollen, cylindrical, darkened by intestinal content; head shape (pl. 13, fig. 2) close to that of worker of *A. wheeleri;* mandibles as shown in figure 2, plate 12, and figure 7, plate 14.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIERS OF *Amitermes emersoni* NEW SPECIES

	Maximum	Minimum	Average	Number measured
Head length	1.18	1.05	1.12	4
Maximum head width	1.03	.95	.99	4
Head width between antero-lateral corners	.75	.65	.69	4
Minimum head width	.82	.71	.77	4
Mandible length	.83	.81	.82	5
Gular length	.60	.56	.58	4
Maximum gular breadth	.34	.31	.33	4
Minimum gular breadth	.33	.30	.31	4
Pronotum width	.54	.47	.50	2
Labrum length	.25	....	....	1
Labrum width	.20	....	....	1
Head index	.93	.84	.88	4
Head contraction index	.80	.73	.77	4
Head-mandible index	.79	.73	....	2
Gular contraction index	.97	.91	.95	4
Inner mandible length	.68	.67	....	2
Mandible curvature	.17	.17	....	2
Mandible curvature index I	.26	.25	....	2
Mandible length used in deriving mandible curvature index II	.83	....	....	1
Minimum mandible curvature	.07	....	....	1
Mandible curvature index II	.08	....	....	1

MEASUREMENTS IN MILLIMETERS OF WORKERS OF *Amitermes emersoni* NEW SPECIES

	Maximum	Minimum	Average	Number measured
True head length	.84	.79	.82	4
Head length to clypeus	.65	.56	.61	4
Head width	.98	.91	.94	4
Distance between mandible articulations	.47	.43	.44	4
Clypeus length	.33	.28	.30	4
Antenna length	1.12	1.00	1.06	4
Mandible length	.48	.47	.47	4
Pronotum length	.29	.25	.26	2
Pronotum width	.54	.47	.51	2
Thorax length	.53	.43	.48	2
Thorax width	.70	.59	.64	2
Abdomen length	1.43	.96	1.19	2
Abdomen width	1.00	.78	.89	2

Biology and distribution.—But little is known of this species. The only three collections were made by Pickens, one from a winter corn patch at Coachella, another from small dead trunks, probably of the desert willow (*Chilopsis*), in the vicinity of Salton on the Salton Sea, and the last from *Chilopsis* mounds near Cathedral City, all in the northern end of the Colorado Desert, Riverside County (fig. U).

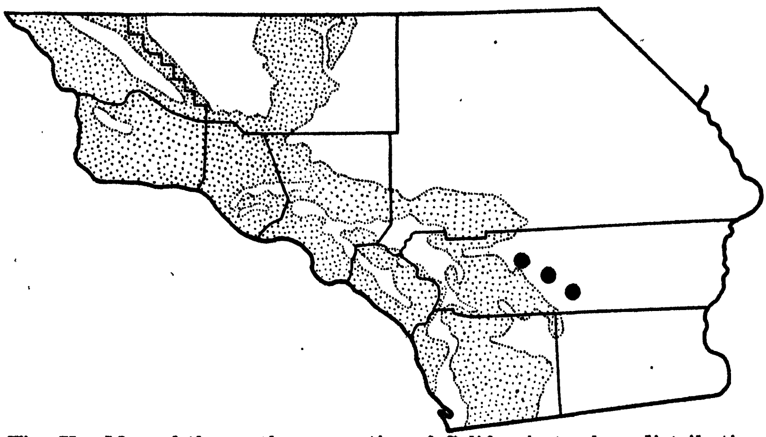


Fig. U. Map of the southern counties of California to show distribution of *Amitermes emersoni* new species. The white area represents the lower Sonoran life zone and the dotted area the other life-zones as defined by Grinnell (1915).

Amitermes silvestrianus new species

Silvestri's desert termite

Plate 14, figures 2, 4, 6, and 8

DIAGNOSIS

Alate unknown.

Soldier. Of the *emersoni* group, nearest to *A. emersoni;* mandibles more strongly curved, mandible curvature index II, 0.11; tooth lower, near middle of mandible, smaller; mandible thicker below tooth; head much less contracted than in *A. emersoni,* head contraction index about 0.95.

DESCRIPTION

Alate unknown.

Soldier. Generally white to light yellow save distal two thirds of mandibles which are light brown. Head (pl. 14, fig. 2) broad oval, sides moderately convex, broadest in middle, postero-lateral corners broadly rounded, but little contracted anteriorly; head relatively low without prominence in fontanel region as in *A. emersoni* (fig. Q). Mandibles (pl. 14, fig. 8) more bent than in *A. emersoni,* left bent at level of tooth; right below tooth; teeth small, not projecting, directed in axis of basal half of mandible; mandible widest (save at base) just distal to tooth. Antennae much as in *A. emersoni.* Gula wider and flatter than in *A. emersoni.*

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF TWO SOLDIERS OF *Amitermes silvestrianus* NEW SPECIES

	A	B
Head length	1.14	1.12
Maximum head width	0.92	0.93
Minimum head width	0.87	0.87
Mandible length	0.92	0.89
Gular length	0.58	.....
Maximum gular breadth	0.34	.....
Minimum gular breadth	0.33	.....
Pronotum width	0.61	0.63
Head index	0.81	0.83
Head contraction index	0.95	0.94
Head mandible index	0.81	0.79
Gular contraction index	0.97	.....

WORKER. Close to *A. emersoni* but head narrower and longer, sides gradually converging posteriorly; mandibles as in figure 8, plate 14.

MEASUREMENTS IN MILLIMETERS OF WORKERS OF *Amitermes silvestrianus* NEW SPECIES

	A	B	C
Head length	0.73	0.76	0.79
Head width	0.83	0.94	0.96
Pronotum width	0.46	0.56	0.60

MEASUREMENTS IN MILLIMETERS OF A REPRODUCTIVE NYMPH OF LAST INSTAR OF *Amitermes silvestrianus* NEW SPECIES

Head length (including labrum)	1.09
Head width (maximum)	0.86
Pronotum width	0.76
Length over all	5.35
Length of mesothoracic wing pads	1.01

Distribution and biology.—The single collection of this species was made by Mr. G. B. Castle of the Termite Investigations Committee in the dry bed of the Whitewater River near Garnet in the upper Coachella Valley.

Amitermes snyderi new species

Snyder's desert termite

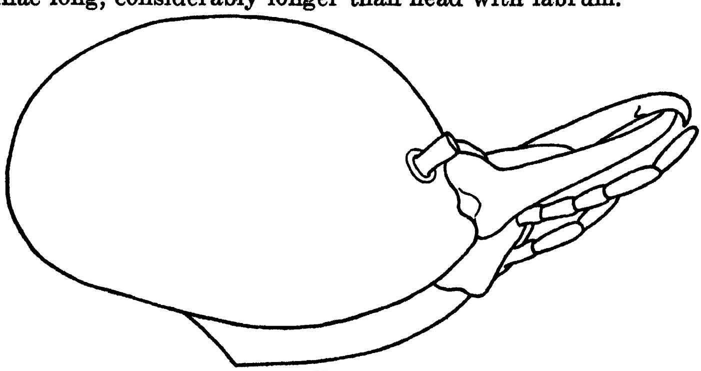
Plate 11, fig 4; plate 12, figures 4 and 9; plate 13, figures 4 and 10; figures V–Y

DIAGNOSES

ALATE. Unknown.

SOLDIER. Large, head capsule about 1.30 mm. wide or wider and about 1.50 mm. long; head broad, oval in dorsal view; head index about 0.9; head broadest just behind middle, sides convex, converging anteriorly; head contraction index about 0.85; head high with rounded dorsal profile; mandibles light save at tips, short and strongly curved, outer ends bent in, nearly at right angles; head-mandible index about 0.62; basal projection large; mandible curvature index I about 0.43, II about 0.16; tooth in outer one-third, projecting somewhat but directed posteriorly due to curvature of mandibles. Gula widened in anterior one-half, shallowly contracted near posterior end; gular contraction index about 0.88. Antennae yellow, about as long as head.

WORKER. Large; abdomen leathery in appearance, ordinarily black from intestinal contents. Head large, about 1.15 mm. wide and about .90 long; head with labrum, circular in outline; second tooth of mandibles shorter than in *A. arizonensis*; third tooth of right mandible prominent; notch between it and basal projection distinct; basal projection prominent, longer than its distance from second tooth; antennae long, considerably longer than head with labrum.



V

W X Y

Figs. V–Y.

Amitermes snyderi new species. All figures camera lucida outlines. × 40.

Fig. V. Head of soldier in lateral view.
Fig. W. Labrum of soldier in dorsal view.
Fig. X. Pronotum of soldier in dorsal view.
Fig. Y. Labrum of worker in dorsal view.

DESCRIPTIONS

SOLDIER. Head and antennae light yellow, mandibles light yellow at base to light reddish brown distally; femora white, tibiae and tarsae pale yellow, basal leg sclerites and thorax pale, rusty brown; abdomen pale yellowish-white with dull gray-black appearance due to abdominal contents. Head broad and massive, thoracic region narrow, abdomen broad, swollen, pointed posteriorly.

Head (pl. 11, fig. 4) very broad oval in dorsal outline, sides more convex than posterior margin; ventral surface of head (fig. V) flat behind, curving sharply up to mandibular articulation; head rounding up from lateral and posterior margins to high, domed central area; sloping downward in anterior quarter at an angle of about 45° save in center which is marked by low sloping, somewhat irregular, fontanel protuberance; reddish hairs, scattered, save in region of fontanel protuberance and particularly about fontanel aperture where numerous and large.

Mandibles as in figure 9 of plate 12; broad, flattened, strongly incurved from about middle, directed somewhat upward from basal articulations (fig. V); teeth in outer one-third, projecting somewhat, but directed backward. Antennae (pl. 11, fig. 4) slender, particularly so in region of segments III–V, slightly longer than head capsule; of 15 segments; segments III–V small, together not much longer than II.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIERS OF *Amitermes snyderi* NEW SPECIES

	Maximum	Minimum	Number measured
Head length	1.55	1.44	2
Maximum head width	1.43	1.27	2
Head width between antero-lateral corners	.99	.95	2
Minimum head width	1.19	1.12	2
Mandible length	.96	.87	3
Gular length	.81	.75	2
Maximum gular breadth	.47	.44	2
Minimum gular breadth	.42	.38	2
Pronotum width	.78	....	1
Labrum width	.36	....	1
Labrum width	.37	....	1
Head index	.92	.88	2
Head contraction index	.88	.84	2
Head-mandible index	.66	.58	2
Gular contraction index	.90	.86	2
Inner mandible length	.79	....	1
Mandible curvature	.34	....	1
Mandible curvature index I	.43	....	1
Mandible length used in deriving mandible curvature index II	.96	....	1
Minimum mandible curvature	.15	....	1
Mandible curvature index II	.60	....	1

Labrum broad (fig. W), somewhat contracted near base, with truncate or broadly rounded tip, hairing sparse, four terminal subequal spines, three or four other hairs on either side, usually in a single row, decreasing posteriorly. Gula (pl. 13, fig. 10) broad, contracted broadly but shallowly in posterior one-half.

Pronotum as in figure X.

Worker. Generally white, with yellow-red spots marking mandible margins and articulations; abdomen a dirty gray-black owing to contents. Head broad, thorax relatively narrow, abdomen swollen. Head (pl. 13, fig. 4) rounded in dorsal view. Mandibles as in figure 4 of plate 12.

Measurements in Millimeters of Workers of *Amitermes snyderi* New Species

	Maximum	Minimum	Average	Number measured
Head length	.95	.84	.89	7
Head length to clypeus	.89	.81	.83	25
Head width	1.18	1.06	1.11	25
Distance between mandible articulations	.64	.50	.54	25
Clypeus length	.31	.28	.29	25
Antenna length	2.19	1.59	1.77	25
Mandible length	.55	.42	.51	25
Pronotum length	.53	.42	.45	25
Pronotum width	.81	.74	.77	25
Abdomen length	2.74	1.89	2.34	25
Abdomen width	1.77	1.30	1.54	25

Biology and distribution.—This species has been taken but six times, all in the Mojave and Colorado deserts. Practically nothing is known of its habits. Each time it was found attacking wood, in local damp areas, at altitudes of from one thousand to two thousand feet.

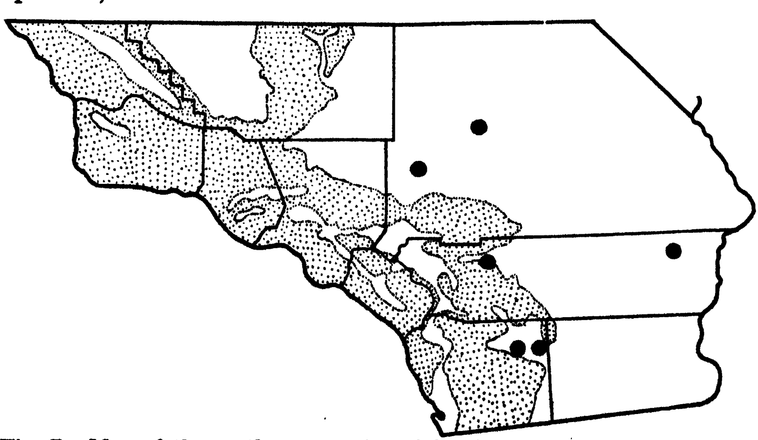


Fig. Z. Map of the southern counties of California to show distribution of *Amitermes snyderi* new species. The white area represents the lower Sonoran life zone and the dotted area the other life-zones as defined by Grinnell (1915).

Pickens found it attacking a redwood post and the roots of desert ironwood (*Olneya*), and in desert willow (*Chilopsis*), cholla, and creosote bush (*Larrea*), and I found it attacking a pine board partly buried in the moist sand, and in fallen branches of *Yucca*.

Amitermes tubiformans Buckley

The tube forming termite (Essig); The tube building desert termite (Light)

Figures A and B

Termes tubiformans Buckley 1863, Proc. Ent. Soc. Phila., 1 (1862): 213.
Hamitermes tubiformans Holmgren, 1912, Kgl. Svensk. Vetensk. Akad. Handl., 48:91.
Amitermes tubiformans Banks, 1920, U. S. Nat. Mus. Bull. 108:55.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIERS OF *Amitermes tubiformans* BUCKLEY

	Maximum	Minimum	Average	Number measured
Head length	1.43	1.33	1.38	3
Maximum head width	1.24	1.18	1.21	3
Minimum head width	1.10	.98	1.04	3
Mandible length	1.24	1.16	1.21	3
Maximum gular breadth	.37	.37	.37	2
Minimum gular breadth	.36	.36	.36	2
Pronotum width	.81	.76	.78	3
Head index	.88	.87	.88	3
Head contraction index	.89	.83	.86	3
Head-mandible index	.87	....	....	1
Gular contraction index	.96	.96	.96	2
Inner mandible length	1.07	....	....	1
Mandible curvature	.28	....	....	1
Mandible curvature index I	.26	....	....	1
Mandible length used in deriving mandible curvature index II	1.18	....	....	1
Minimum mandible curvature	.12	....	....	1
Mandible curvature index II	.10	....	....	1

Amitermes wheeleri Desneux

Wheeler's termite (Essig); Wheeler's desert termite (Light)

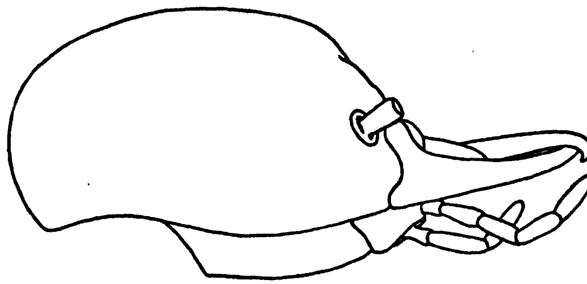
Plate 11, figure 3; plate 12, figure 8; plate 13, figures 3 and 9; figures AA–DD

Termes wheeleri Desneux 1905, Ann. Soc. Ent. Belg.
Amitermes wheeleri Banks, 1920, U. S. Nat. Mus., Bull. 108.

DIAGNOSES

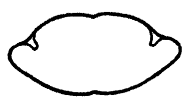
SECOND FORM REPRODUCTIVE. Head about 1.05 mm. wide and 1.32 mm. long; fontanel large, irregular; ocellus about twice as long as broad, separated from eye by somewhat more than its own long diameter; antennal spot as wide as twice the length of ocellus; pronotum about 0.55 mm. long and 1.02 mm. wide.

Soldier. Small, head considerably less than 1 mm. wide; head index about 0.78; head broadest near posterior end, sides nearly straight, converging anteriorly, head contraction index about 0.90; head high in front, frons declivitous (fig. AA); mandibles (pl. 12, fig. 8) red, broad, curved throughout; basal projections large, left basal projection with irregularly convex face; head-mandible index about 0.70; teeth below middle, somewhat projecting, directed mediad and basally, separated from basal projections by a deep broad notch with curved inner margin; no notch in lateral margin at tooth level; gula broad in proportion to head; gular contraction index about 0.90; antennae short, about as long as head, very pale yellow.

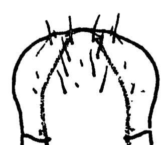


AA

BB



CC



DD

Figs. AA–DD. *Amitermes wheeleri* Desneux. All figures camera lucida outlines, × 40.

Fig. AA. Head of soldier in lateral view.
Fig. BB. Labrum of soldier in dorsal view.
Fig. CC. Pronotum of soldier in dorsal view.
Fig. DD. Labrum of worker in dorsal view.

Worker. Small; head white, not more than 0.90 mm. wide; thorax narrow, white; abdomen in life slender; intestinal contents brown in life, gray brown in preservation; antennae short, white; mandibles small, first two teeth short, blunt; basal projection of left mandible strongly convex posteriorly; outer margin of left mandible straight.

Second form reproductive. Generally well pigmented, brown to brownish yellow; eyes black with brownish tinge, surrounded by pale zone; body generally heavily haired; wing pads narrow, margined with dense zone of long hairs, anterior wing pad extending considerably beyond posterior border of metathorax; thorax swollen; a distinct white suture between dorsal sclerites and lateral chitin.

Head, with mouth parts, elongate, rounded behind, parallel-sided; mouth parts large and elongate; eyes circular, flat; ocelli distinct, small, directed anteriorly and medially at angle of 45° to transverse

axis, about twice as long as wide, separated from eye by somewhat more than their long diameter and from antennal spots by somewhat less than their long diameter; antennal spots, distinct, semilunar, as wide as twice the length of ocellus; fontanel large, white, irregular, marked posteriorly by pigmented border; fontanel arising from anterior half of circular, yellowish spot, clear of hairs, presumably marking location of cephalic gland; postclypeus yellow, swollen, with slightly concave anterior border and strongly convex posterior border; anteclypeus white, when labrum is extended, as long as postclypeus; labrum flat, yellow, spatulate with narrow proximal region, leaving uncovered much of basal area of swollen mandibles; Y-suture abortive, its arms marked by irregular white lines beginning a little more than long diameter of ocellus in front of fontanel and ending about long diameter of ocellus from antennal spots, at about level of posterior border of antennal spots.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIERS OF *Amitermes wheeleri* DESNEUX

	Maximum	Minimum	Average	Number measured
Head length	1.12	1.04	1.07	5
Maximum head width	.89	.78	.84	5
Head width between antero-lateral corners	.68	.61	.65	5
Minimum head width	.76	.74	.76	3
Mandible length	.81	.71	.76	5
Gular length	.60	.51	.56	5
Maximum gular breadth	.31	.26	.30	5
Minimum gular breadth	.28	.24	.26	5
Pronotum width	.57	.51	.53	5
Labrum length	.31	.25	....	2
Labrum width	.31	.25	....	2
Head index	.81	.75	.78	5
Head contraction index	.90	.89	.90	3
Head-mandible index	.76	.67	.71	5
Gular contraction index	.94	.80	.86	5

MEASUREMENTS IN MILLIMETERS OF WORKERS OF *Amitermes wheeleri* DESNEUX

	Maximum	Minimum	Average	Number measured
True head length	.77	.68	.73	5
Head length to clypeus	.62	.59	.60	25
Head with	.80	.77	.78	25
Distance between mandible articulations	.39	.33	.37	25
Clypeus length	.24	.18	.21	25
Antenna length	1.00	.71	.88	25
Mandible length	.44	.28	.33	25
Pronotum width	.53	.42	.48	25
Thorax length	.89	.47	.65	25
Thorax width	.65	.47	.55	25

Pronotum with nearly straight, slightly emarginate anterior border; antero-lateral corners rounded; sides receding strongly to join short, weakly concave, posterior border; mid-longitudinal line narrow but distinct, a wider, somewhat sinuous white line marking inner half of transverse groove.

Measurements in Millimeters of Second Form Reproductive of *Amitermes wheeleri* Desneux

Head length (to tip of labrum)	1.32
Maximum head width	1.04
Pronotum length	.54
Pronotum width	1.02
Thorax length	1.22
Abdomen length	2.49
Abdomen width	1.39

Distribution.—Banks and Snyder report this species as common in Texas. A collection made for the Termite Investigations Committee by Mr. and Mrs. A. W. Keller, near Tucson, is the only Arizona record. There is good reason to believe it to be present throughout the southern region of that State, however, since the collections of the Termite Investigations Committee have shown it to be common in the Colorado Desert region in California (fig. EE), and a collection from Rice (Pickens) and two collections from the western margin of the Mojave Desert (fig. EE) seem to place it as a member of the fauna of that desert.

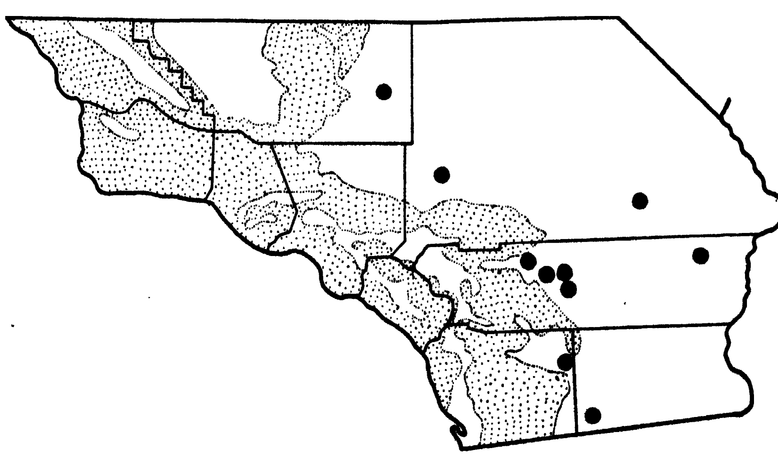


Fig. EE. Map of the southern counties of California to show distribution of *Amitermes wheeleri* Desneux. The white area represents the lower Sonoran life zone and the dotted area the other life-zones as defined by Grinnell (1915).

Biology (see also Snyder, 1920).—This species has not been found building covered ways above ground, but is commonly found attacking wood of poles, posts, stakes, etc., in the ground, and dead desert shrubs or the dead portions of living shrubs. At Whitewater Station in the Colorado Desert, I found it very common in cow chips. Snyder (1920) reports it as doing serious damage to wooden structures, and Pickens and Harvey found it attacking butts of telephone poles near Indio. In most cases, the damage done was not comparable with that done by *Neotermes simplicicornis* (Banks). In one case, however, the damage was extensive, and a remarkable feature was the apparent preference shown for the hard portion (summer wood) of the annual ring. In another case a redwood pole was attacked, cylindrical covered ways being built over the surface. The galleries within were angular or rectangular in cross-section. The attack extended from ground level to forty inches below ground.

Pickens has noted that this species seems to be very tolerant of individuals introduced from other colonies, although this may have been due to unnatural laboratory conditions.

Pieces of mesquite, cholla, and other desert wood on or partly buried in the ground, especially in or near the desert washes, are favorite food sources for this species. In such a location Pickens found the supplementary reproductives described above. I found it very abundant in the bases of dead stalks of ocotillo (*Fouquiería*) near the foot of the Coyote Mountains on the El Centro-San Diego highway.

Soldiers are few, at least in the surface workings of this species, and in many cases the most careful search failed to reveal one among the hundreds of workers found in cow chips. As is true of other *Amitermes* species, the workers tend to run in parallel columns when disturbed, a habit common to many species of the family Termitidae.

It was often found in cow chips in the upper Coachella Valley very close to colonies of *Reticulitermes tibialis* Banks, so that upon opening up the chip, they seemed to be associated. In several instances a native ant, *Cremastogaster coarctata* Mayr., was found in cow chips in types of working indistinguishable from those of this *Amitermes*. Similar workings found occupied by these ants in desert plants and others vacant of either ants or termites led to the belief that many termite colonies or branch colonies are destroyed by these ants.

Amitermes coachellae new species

Coachella desert termite

Plate 12, figure 3; plate 14, figures 1, 3, 5, and 9; plate 15

Extensive collections very recently made by Mr. G. B. Castle and Mr. O. L. Williams of the staff of the Termite Investigations Committee, in the upper end of Coachella Valley, Riverside County, the northernmost extension of the Colorado Desert in California, include several vials of termites evidently related to *A. wheeleri*, but differing from it markedly in size and other characters as brought out below. These differences are such as to mark this as a different species in the light of our present knowledge of the range of variation in *A. wheeleri* and it becomes necessary to give it a separate specific designation. The study of the alates and of more extensive collections of soldiers may show intergradation with *A. wheeleri*. If so, that species has a most remarkable range of variation.

Time and space permit but brief diagnoses, and measurements of the soldier and worker of the new species.

DIAGNOSES

Alate unknown.

Soldier. Of the *wheeleri* group. Large, head 1 mm. or more in breadth; head quadrangular, head contraction index about 0.95; head much lower in proportion than in *A. wheeleri;* frons not declivitous, less extensive and less hirsute than in *A. wheeleri;* mandibles (pl. 14, fig. 9) bent in from level of teeth, abruptly and strongly inbent distally; notch deep but short and angular; left basal projection with straight face; teeth not projecting, sharp, directed basally; gula hardly contracted.

Worker. Large; abdomen long and slender in life (much contracted in preservation); contents of abdomen dark, dirty gray to black; head round, yellow; antennae long, yellow; mandibles large, first two teeth long and sharp, the first much longer than the second.

Biology and distribution.—Of the six collections of this new species five were taken in a narrow zone two miles long, situated along the Southern Pacific Railway Company's right of way, ending some two miles northwest of Palm Springs Station and having an elevation of 1200–1300 feet. The other collection was taken in Mission Canyon about eleven miles northeast at an altitude of about 1800 feet.

The colonies were all found in sand. In several cases they were found attacking casual wood, usually buried pieces, penetrating it as does *A. wheeleri*. They build carton-lined runways through the sand and around rocks, etc.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIERS OF *Amitermes coachellae* NEW SPECIES

	A	B	C
Head length	1.36	1.35	1.32
Head width	1.02	1.04	....
Minimum head width	.96	0.96	....
Mandible length	.86	0.90	0.86
Gular length	.68	0.66	....
Maximum gular breadth	0.35	0.33	....
Minimum gular breadth	0.33	0.34	0.34
Pronotum width	0.66	0.66	....
Head index	0.75	0.77	....
Head-contraction index	0.94	0.92	....
Head mandible index	0.63	0.67	0.65
Gular contraction index	0.94	1.03	1.00

MEASUREMENTS IN MILLIMETERS OF WORKERS OF *Amitermes coachellae* NEW SPECIES

	A	B	C
Head length	0.83	0.84	0.84
Head width	1.00	1.01	1.00
Pronotum width	0.60	0.68	0.68

Tropical species of *Amitermes* are known to produce nests of various types. No nests have been reported, however, for any of the Nearctic species. This gives considerable interest, therefore, to the discovery by Mr. Castle of a large, well-formed nest of this species, a portion of which is seen in plate 15. The nest is largely composed of a compact, dark brownish-black material which has the appearance of earth but is largely, if not entirely, carton. The nest was 24 inches high and about 24 inches in circumference at the ground line. It was somewhat pear-shaped, with a narrow exposed portion some six inches high, the remainder buried in the packed sand into which in all directions ran numbers of runways lined with the characteristic dark carton material. The base of the nest which was built around the roots of a dead plant was deserted, the great majority of the termites being found in the upper half of the nest.

LITERATURE CITED

Banks, N., and T. E. Snyder

1920. A revision of the Nearctic Termites (Banks) with notes on their biology and geographical distribution (Snyder). U. S. Nat. Mus., Bull. **108**:1–228, pls. 1–35, 70 figs in text.

Buckley, S. B.

1863. Descriptions of two new species of termites from Texas. Proc. Ent. Soc. Philadelphia, 1 (1862):212–215.

Desneux, J.

1905. Varieties termitologiques. Ann. Soc. Ent. Belg., **49**:336–360.

Essig, E. O.

1926. Insects of western North American (New York, Macmillan), i–ix + 1035, 766 figs. in text.

Grinnell, J.

1915. A distributional list of the birds of California. Pacific Coast Avifauna, **11**.

Light, S. F.

1927. A new and more exact method of expressing important specific characters of termites. Univ. Calif. Publ. Entom., **4**:75–88, 2 figs. in text.

1929. Termites and termite damage. Univ. Calif. Agr. Exp. Sta., Circular 314.

Light, S. F., M. Randall, and F. G. White

1930. Termites and termite damage with preliminary recommendations for prevention and control. Univ. Calif. Agr. Exp. Sta., Circular 318.

EXPLANATION OF PLATES

PLATE 10

Earthen tubes built by *Amitermes arizonensis* Banks about desert vegetation and left empty after the plant was entirely eaten away. Natural size.

PLATE 11

Photomicrographs of the heads of soldiers of California species of *Amitermes*.

Fig. 1. *Amitermes californicus* Banks. × 25.
Fig. 2. *Amitermes emersoni* new species. × 23.5.
Fig. 3. *Amitermes wheeleri* Desneux. × 25.
Fig. 4. *Amitermes snyderi* new species. × 25.
Fig. 5. *Amitermes arizonensis* Banks. × 25.

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PLATE 12

Photomicrographs of mandibles of workers and soldiers of California species of *Amitermes*. × 32.

Fig. 1. Much worn mandibles of worker of *Amitermes californicus* Banks.
Fig. 2. Much worn mandibles of worker of *Amitermes emersoni* new species.
Fig. 3. Mandibles of worker of *Amitermes coachellae* new species.
Fig. 4. Mandibles of worker of *Amitermes snyderi* new species.
Fig. 5. Mandibles of worker of *Amitermes arizonensis* Banks.
Fig. 6. Mandibles of soldier of *Amitermes californicus* Banks.
Fig. 7. Mandibles of soldier of *Amitermes emersoni* new species.
Fig. 8. Mandibles of soldier of *Amitermes wheeleri* Desneux.
Fig. 9. Mandibles of soldier of *Amitermes snyderi* new species.
Fig. 10. Mandibles of soldier of *Amitermes arizonensis* Banks.

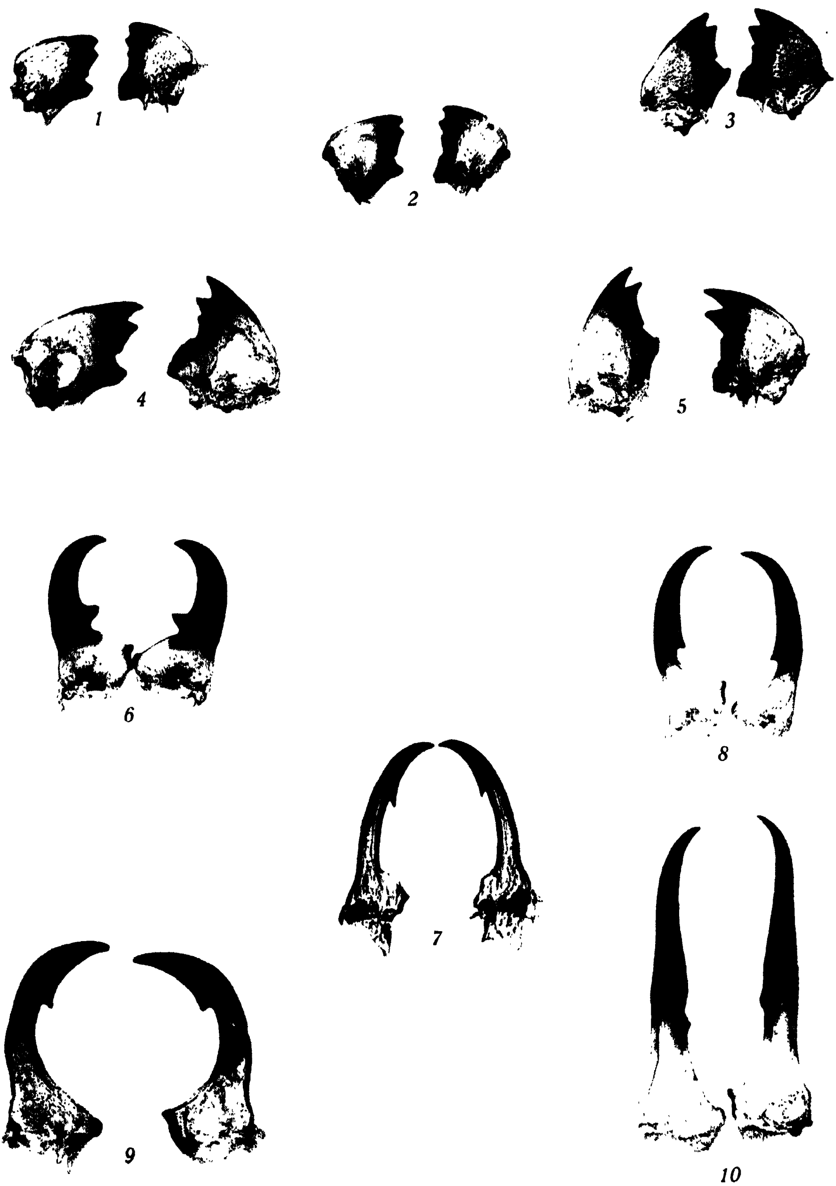

PLATE 13

Photomicrographs of heads of workers and gulae of soldiers of California species of *Amitermes.*

Fig. 1. Head of worker of *Amitermes californicus* Banks. × 22.7.
Fig. 2. Head of worker of *Amitermes emersoni* new species. × 24.5.
Fig. 3. Head of worker of *Amitermes wheeleri* Desneux. × 22.7.
Fig. 4. Head of worker of *Amitermes snyderi* new species. × 22.7.
Fig. 5. Gula of soldier of *Amitermes californicus* Banks. × 32.
Fig. 6. Head of worker of *Amitermes arizonensis* Banks. × 22.7.
Fig. 7. Gula of soldier of *Amitermes arizonensis* Banks. × 32.
Fig. 8. Gula of soldier of *Amitermes emersoni* new species. × 32.2.
Fig. 9. Gula of soldier of *Amitermes wheeleri* Desneux. × 32.
Fig. 10. Gula of soldier of *Amitermes snyderi* new species. × 32.


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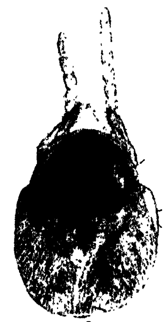
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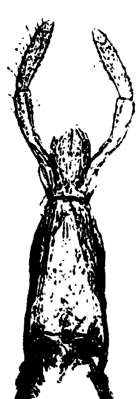
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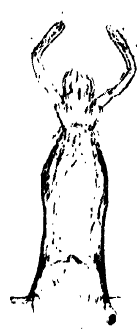
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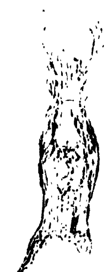
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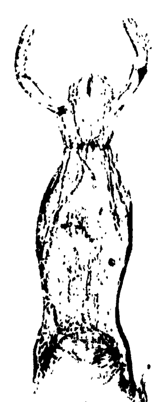
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PLATE 14

Photomicrographs of head and mandibles of workers and soldiers of *Amitermes silvestrianus* new species and *Amitermes coachellae* new species. *Ca.* × 28.

Fig. 1. *Amitermes coachellae* new species, head of soldier.

Fig. 2. *Amitermes silvestrianus* new species, head of soldier with mandibles removed.

Fig. 3. *Amitermes coachellae* new species, mandibles of worker.

Fig. 4. *Amitermes silvestrianus* new species, head of worker.

Fig. 5. *Amitermes coachellae* new species, head of worker.

Fig. 6. *Amitermes silvestrianus* new species, mandibles of worker.

Fig. 7. *Amitermes emersoni* new species, mandibles of worker.

Fig. 8. *Amitermes silvestrianus* new species, mandibles of soldier.

Fig. 9. *Amitermes coachellae* new species, mandibles of soldier.

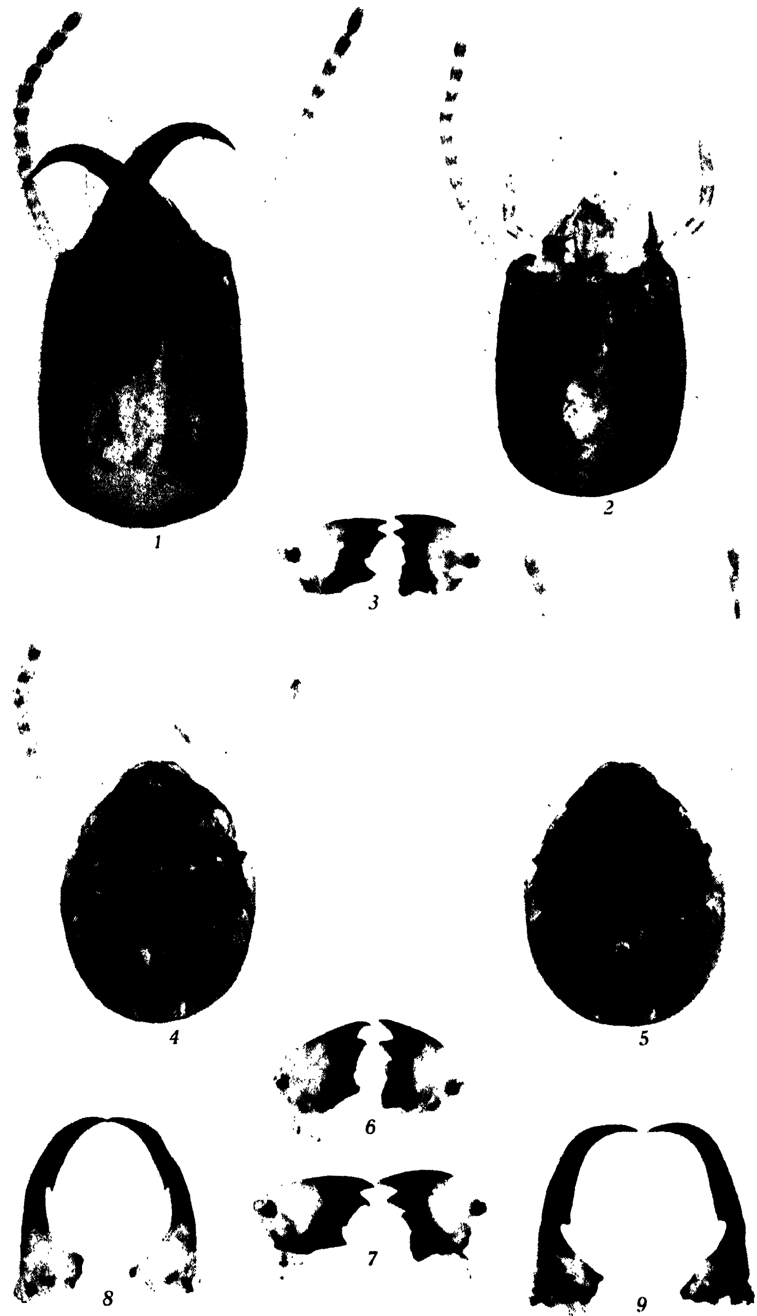
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PLATE 15

Photograph of broken inner surface of upper exposed portion of nest of *Amitermes coachellae* new species. *Ca.* $\times$ 1.

THE MEXICAN SPECIES OF *AMITERMES* SILVESTRI (ISOPTERA)

BY

S. F. LIGHT

In a recent paper (1930) I have given descriptions of soldiers and workers, and a key to the soldier caste of the eight species of *Amitermes* Silvestri found in the United States, of which the soldier caste is known. The present paper is based on the material collected during a recent trip into western Mexico for the Termite Investigations Committee. It includes descriptions of four new species of *Amitermes,* as well as a key to the soldiers of all the New World species of the genus from British Guiana northward save two, *A. confusus* Banks and *A. perplexus* Banks, which are based on alates only. A later paper will report the complete collection made in Mexico.

In the previous paper (1930) it was pointed out that the Nearctic species of *Amitermes* fall into seemingly fairly distinct groups on the basis of soldier characters. The fourteen American species from the area under consideration may be referred to the five groups there suggested. With the additional species here described it becomes possible to characterize these groups more or less completely as follows:

1. The TUBIFORMANS group. Large species, head width 1.25 millimeters or more, head not greatly longer than wide, head index somewhere near 0.9. Mandibles (pl. 17, figs. 1 and 2) relatively long, head-mandible index 1.0 or more save in *A. nigriceps* new species; mandibles relatively straight, without extensive distal incurvature and hence with cutting surfaces usually closely approximated when directed anteriorly. Teeth below middle of mandible, relatively small, directed mediad, located in notches in the cutting surface. Pigmentation greater than in other groups, in that antennae of workers and soldiers are darkened, often smoky, and head of workers yellow to smoky-brown. Gular contraction very slight or lacking, gular contraction index about 1.0.

To this well defined group belong four species:

A. tubiformans Buckley, New Mexico, Texas and northern Mexico (Banks and Snyder 1920).
A. arizonensis Banks, southeastern California, Arizona (Banks and Snyder 1920), and Empalme and Mazatlan, coastal western Mexico.
A. grandis new species, Tepic and Guadalajara, tableland of western Mexico.
A. nigriceps new species, Jala, near Colima, coastal slopes of western Mexico.

2. The WHEELERI group. Head usually long and narrow, little if at all contracted; head index less than 0.8 and head contraction index about 0.9. Teeth near base of mandibles, small, succeeded proximally by a deep notch (pl. 17, fig. 7).

Here I have placed three species:

Amitermes wheeleri Desneux, southeastern California (Light 1930), Arizona, and Texas (Banks and Snyder 1920, Light 1930).
Amitermes coachellae Light (1930), southeastern California.
Amitermes cryptodon new species, Jala, near Colima, coastal slope of western Mexico.

The mandibles of *A. cryptodon* differ rather widely from those of *A. wheeleri* and it may represent another separate group.

3. The SNYDERI group. Large species, head well over 1.25 millimeters wide, head ovate, sides convex, and widest near middle; head index about 0.9; head contraction index about 0.85. Mandibles large, rough, strongly bent and incurved from below the middle; teeth in outer one-third, basally directed, barb-like.

Here is placed a single species, *A. snyderi* Light (1930) from southeastern California, which a more complete series of species may show to belong with the next group.

4. The EMERSONI group. Intermediate in size. Head oval to subrectangular. Mandibles slender (pl. 17, fig. 6), regularly curved; teeth barb-like, in distal one-half of mandible.

Here I place four species:

A. emersoni Light (1930), southeastern California.
A. silvestrianus Light (1930), southeastern California.
A. beaumonti Banks, Panama (Banks 1918).
A. ensifer new species, Colima, coastal slope of western Mexico.

5. The CALIFORNICUS group. Medium sized to large species. Head broadest behind middle. Mandibles strongly curved in distal one-third. Teeth below middle, directed mediad, conical (pl. 17, figs. 3–5), strongly projecting, not set in notches.

Here I have placed three species:

A. californicus Banks, southeastern California, Arizona (Banks and Snyder 1920, Light 1930), and Mazatlan, on the coast, and Colima, on the coastal slope of western Mexico.

A. excellens Silvestri, Kartabo, British Guiana (Silvestri 1923, Emerson 1925).

A. medius Banks, Panama (Banks 1918).

More careful comparative study may show this also to be a composite group.

PRACTICAL KEY TO SOLDIERS OF THE NORTHERN NEW WORLD SPECIES OF *AMITERMES* SILVESTRI

1. Antennae conspicuously darkened distally; mandibles (pl. 17, figs. 1 and 2) long, often as long as head or longer, straight or nearly straight save for tips; teeth in proximal half of mandibles relatively small, directed inward 2
   Antennae not conspicuously darkened distally, never smoky; mandibles shorter, usually much shorter than head, curved throughout; teeth either large or directed backward or distally located 6
2. Antennae of soldiers (and workers) blackened distally 3
   Antennae of soldiers (and workers) brown to at most light smoky distally 4
3. Mandibles as long as head, much longer than width of head .... 1. **A. arizonensis** Banks
   Mandibles considerably shorter than head, not much longer than width of head (pl. 16, fig. 5) .... 2. **A. nigriceps** new species
4. Mandible bases brown .... 3. **A grandis** new species
   Mandible bases yellow 5
5. Mandibles not so long as head; bent from near middle; tooth near middle .... 4. **A. tubiformans** Buckley
   Mandibles about as long as head or longer, very straight, curved only near tip (pl. 17, fig. 2); tooth much below middle .... **A. arizonensis** Banks
6. Teeth in distal one-half of mandible, directed posteriorly 7
   Teeth not in distal one-half 11
7. Mandibles massive, rugged .... 5. **A. snyderi** Light
   Mandibles slender, smooth (pl. 17, fig. 6) 8
8. Mandibles strongly curved; mandible curvature index II more than 0.16 .... 6. **A. beaumonti** Banks
   Mandibles less strongly curved; mandible curvature index II less than 0.12 9
9. Tooth near middle of mandible .... 7. **A. silvestrianus** Light
   Tooth in distal one-third of mandible 10
10. Mandibles very slightly curved; teeth very sharp; sides of head nearly parallel posteriorly (pl. 16, fig. 2) .... 8. **A. ensifer** new species
    Mandibles more strongly curved, teeth blunter; sides of head converging .... 9. **A. emersoni** Light

11. Teeth small, projecting but little, set off by a deep proximal notch (pl. 17, fig. 7) 12
    Teeth larger, directed mediad, projecting, no deep proximal groove....................14
12. Outer margins of mandibles evenly convex (pl. 17, fig. 7) ....
    ....10. **A. cryptodon** new species
    Outer margins of mandibles distinctly convex, tips strongly so....................13
13. Smaller, head less than one millimeter in diameter; head high in proportion to length ....11. **A. wheeleri** Desneux
    Larger, head more than one millimeter in diameter; head lower in proportion to length ....12. **A. coachellae** Light
14. Tooth near middle of mandible (pl. 17, fig. 5)....................13. **A. medius** Banks
    Tooth near base of mandible (pl. 17, figs. 3, 4)....................15
15. Tooth small, head width greater than 1.5 mm....................14. **A. excellens** Silvestri
    Tooth large (pl. 17, figs. 3, 4); head width less than 1.2 mm....................
    ....15. **A. californicus** Banks

In the systematic discussion and descriptions following, dimensions and indices are used as defined in the preceding paper (1930).

Amitermes arizonensis Banks

Plate 17, figure 2; plate 18, figure 5

A collection taken at Presidio, near Mazatlan, in a cow chip, consists of two soldiers and several workers. These agree closely with *A. arizonensis* in all characters save color, as the measurements and indices given below will show. The antennae of both workers and soldiers are distally smoky black (pl. 18, fig. 5), much darker than any yet reported. Likewise the worker head is a smoky yellow-brown. More complete collections may show this melanism to be associated with conditions of unusual moisture as has been shown to be the case with other animals. This collection adds very greatly to the known range of *A. arizonensis.*

Measurements in Millimeters, and Indices, of the Two Soldiers of *A. arizonensis* Taken near Mazatlan

	A	B
Head length	1.28	1.28
Maximum head width	1.15	1.15
Minimum head width	1.07	1.07
Mandible length	1.19	1.24
Gular length	0.67	0.68
Maximum gular breadth	0.34	0.33
Minimum gular breadth	0.34	0.32
Pronotum width	0.84	0.85
Head index	0.90	0.90
Head contraction index	0.93	0.93
Head-mandible index	0.93	0.97
Gular contraction index	1.00	0.97

Amitermes nigriceps n. sp.

Plate 16, figure 5; plate 18, figure 2

DIAGNOSES

Alate unknown.

Soldier.—Of the *tubiformans* group; bodies of distal antennal segments dark, smoky, black-brown; head index about 0.90; head contraction index 0.90 or less; mandibles short, head-mandible index about 0.78; mandibles bent slightly at level of teeth, making a slightly convex lateral margin; teeth slender, very sharp, located slightly beyond proximal third, in concavities in cutting face of mandibles, left somewhat more distal.

Worker.—Body long, slender; antennae distally smoky black-brown; head capsule a smoky brown, interrupted by pale whitish stripes; head broad, rounded in general contour, broadest in front, sides receding and rounding broadly into strongly convex posterior border.

DESCRIPTIONS

Soldier.—Mandibles proximal to teeth light yellow, distal to teeth light red; basal three segments of antennae white, bodies of next three increasingly dark, remainder dark smoky brown-black; other parts white or very light yellow.

Head (pl. 16, fig. 5) broad oval in dorsal view, not greatly longer than broad, head index about 0.90; sides slightly convex, converging somewhat anteriorly, head contraction index about 0.90, widest posterior to the middle; postero-lateral corners broadly round, posterior margin very weakly convex; mandibles (pl. 16, fig. 5) comparatively short, much shorter than head, head-mandible index about 0.78; lateral margin of mandibles only slightly and somewhat angularly convex, due to a slight hump marking a slight inbending of the mandibles at the level of the tooth; tip of mandible curved about as in *A. arizonensis;* base of mandible somewhat more massive than in *A. arizonensis*; teeth at about same distance from base as in *A. arizonensis* or slighly more distal but mandible distal to tooth much shorter, throwing the teeth but slightly below the middle of the mandible; teeth prominent, slender, very sharp, directed mediad, set in concavities of the inner edge of the mandible deeper than those of *A. arizonensis*; left tooth slightly more distal than right; antennae of 15 segments, without distinctive features; gula slightly more narrowed than in *A. arizonensis,* gular contraction index about 0.94.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIER OF *Amitermes nigriceps* n. sp.

	Millimeters
Head length	1.44
Maximum head width	1.27
Minimum head width	1.14
Mandible length	1.10
Gular length	0.71
Maximum gular breadth	0.35
Minimum gular breadth	0.33
Pronotum width	0.90
Head index	0.88
Head contraction index	0.90
Head-mandible index	0.76
Gular contraction index	0.94

Minimum mandible curvature, 0.09
Mandible curvature index II, 0.082

Worker.—Body long, slender; antennae colored as in soldier; head (pl. 18, fig. 2) smoky brown striped with light areas; head capsule broad, broadest near anterior end, converging posteriorly, sides receding and rounding into strongly convex posterior margin.

MEASUREMENTS IN MILLIMETERS OF FIVE WORKERS OF *A. nigriceps* n. sp.

	Minimum	Maximum	Average
Head length	1.02	1.05	1.04
Head width	1.12	1.17	1.14
Pronotum width	0.69	0.73	0.72

Biology and distribution.—This species was taken only at Jala, (800 ft.), 21 kilometers west of Colima, where three colonies were found, all attacking wood on the ground, in one case a tie in the main line of the National Railway lines. They had built dark covered ways over and through the wood.

Amitermes grandis n. sp.

Plate 16, figures 1 and 4; plate 17, figure 1; plate 18, figure 4

DIAGNOSES

Alate unknown.

Soldier.—Of the *tubiformans* group. Large, head more than 1.5 millimeters wide; mandibles shorter than head, bent inward from basal one-third and with strongly incurved ends; bases of mandibles heavy, rough, and brown, darker than for other species of the group.

Worker.—Large, sides of head parallel anteriorly, antennae long, bodies of distal segments smoky black; clypeus fully as long as wide.

DESCRIPTIONS

Alate unknown.

Soldier.—Large, body short and stout, generally light, but antennae with first three segments white, next two yellow, remainder increasingly smoky; mandibles with light brown bases, red distally. Head (pl. 16, figs. 1, 4) broad ovate, broadest behind middle, sides convex and distinctly converging from behind the middle, particularly in anterior one-half; posterior margin of head strongly convex; head index about 0.90, head contraction index about 0.80; head not particularly high, highest slightly behind middle descending in both directions, flatly in front and convexly behind. Mandibles (pl. 17, fig. 1) shorter than the head, bent in from basal one-third, and with strongly incurved ends throwing mandibles much farther apart when directed forward than for other members of the *tubiformans* group. Antennae of 15 segments, relatively slender; gula very slightly contracted if at all.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIERS OF *Amitermes grandis* n. sp.

	Minimum	Maximum	Average	Number measured
Head length	1.44	1.55	1.49	5
Maximum head width	1.27	1.36	1.33	5
Minimum head width	1.01	1.07	1.04	5
Mandible length	1.26	1.36	1.32	5
Gular length	....	0.79	....	1
Maximum gular breadth	....	0.33	....	1
Minimum gular breadth	....	0.33	....	1
Pronotum width	0.81	0.88	0.84	4
Head index	0.88	0.90	0.89	5
Head contraction index	0.77	0.80	0.78	5
Head mandible index	0.87	0.93	0.89	5
Gular contraction index	....	1.00	....	1
Minimum mandible curvature, 0.12				1
Mandible length used in deriving mandible curvature index II, 1.36				1
Mandible curvature index II, 0.088				1

Worker.—Large; head (pl. 18, fig. 4) yellow, overlaid with pale smoky brown; head broad, sides parallel rounding into flat posterior margin; antennae long, well formed, basal three segments white, bodies of fourth to seventh increasingly dark, bodies of remainder smoky black; clypeus long, fully as long as maximum width, anterior margin convex.

MEASUREMENTS IN MILLIMETERS OF FIVE WORKERS OF *Amitermes grandis* n. sp.

	Minimum	Maximum	Average
Head length	0.94	1.00	0.97
Head width	1.10	1.16	1.12
Pronotum width	0.69	0.76	0.73

Biology and distribution.—This species was taken but twice, both times in and under cow chips in dry, open, sandy spots; once at a point about 10 kilometers north of Tepic and again at La Venta, some 20 kilometers west of Guadalajara.

Amitermes cryptodon n. sp.

Plate 16, figure 3; plate 17, figure 7; plate 18, figure 3

DIAGNOSES

Alate unknown.

Soldier.—Of the *wheeleri* group. Teeth very low on mandible, shelf-life, projecting but little, proximal notch angular; mandibles bent in from tooth level, only slightly convex, tips but little incurved; base of mandible relatively small; mandibles tapering from tooth to tip, very slender in distal one-third; gular contraction index about 0.75.

Worker.—Very small; pale; head width about 0.8 millimeters; antennae short, nymph-like; clypeus only about one-half as long as broad.

DESCRIPTIONS

Alate unknown.

Soldier.—Small; body generally white; head light yellow; antennae yellow, distally dark, slightly smoky, yellow; mandibles red with very short yellow basal portion. Head (pl. 16, fig. 3) long, broadly ovate, sides very faintly convex, converging slightly but gradually from widest point, behind the middle; posterior margin weakly convex; postero-lateral corners rounded; head index about 0.78; head contraction index about 0.88; head high, highest at anterior third, sloping gently back to rounded posterior end, frons flat, steeply declivitous. Mandibles (pl. 17, fig. 7) slightly shorter than head, evenly but weakly convex throughout, tips only slightly more curved than body of mandibles; mandibles tapering from maximum breadth at teeth to very slender distal region; head-mandible index about 0.96; teeth shelf-like, not projecting, set off by deep proximal notch in mandible; antennae of 14 segments; gula strongly and evenly contracted, narrowest near middle, gular contraction index about 0.75.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIERS OF *Amitermes cryptodon*, n. sp

	Minimum	Maximum	Average	Number measured
Head length	1.15	1.20	1.17	6
Maximum head width	0.85	0.93	0.89	6
Minimum head width II	0.76	0.81	0.79	6
Mandible length	1.07	1.10	1.08	6
Gular length	....	0.77	....	1
Maximum gular breadth	....	0.30	....	1
Minimum gular breadth	....	0.22	....	1
Pronotum width	0.49	0.54	0.51	5
Head index	0.73	0.79	0.76	6
Head contraction index	0.87	0.91	0.89	6
Head mandible index	0.90	0.94	0.92	6
Gular contraction index	....	0.73	....	1
Mandible length used in deriving mandible curvature index II, 1.05				1
Minimum mandible curvature, 0.09				1
Mandible curvature index II, 0.086				1

Worker.—Very small; pale and nymph-like; head (pl. 18, fig. 3) light yellow; antennae short, nymph-like; clypeus short, twice as wide as long, sides convex, rounding into anterior margin.

MEASUREMENTS IN MILLIMETERS OF FIVE WORKERS OF *Amitermes cryptodon* n. sp.

	Minimum	Maximum	Average
Head length	0.69	0.77	0.72
Head width	0.80	0.85	0.82
Pronotum width	0.51	0.57	0.55

Biology and distribution.—This species was taken twice at Jala, some 21 kilometers west of Colima, and twice at Madrid, about 28 kilometers west of Colima. These localities are considerably lower and dryer than Colima and support a highly diversified termite fauna. *A. cryptodon* was found in all cases attacking wood, usually decayed, in and on the ground. They were seen to make earthen galleries in and on the wood attacked. They were commonly found in close proximity to other genera and species in similar situations.

Amitermes ensifer n. sp.

Plate 16, figure 2; plate 18, figure 1

DIAGNOSES

Alate unknown.

Soldier.—Of the *emersoni* group. Head long and narrow, rectangular in dorsal view, save for contraction near anterior end; head index about .80; mandibles only weakly convex; tips not strongly incurved; gular contraction index about 0.70.

Worker.—Medium sized, head less than 1.15 millimeters wide; head pale yellow; antennae very short, nymph-like; clypeus about as long as wide.

DESCRIPTIONS

Alate unknown.

Soldier.—Generally white to light yellow, save mandibles which are a light reddish-brown. Head (pl. 16, fig. 2) rectangular in dorsal view, contracted only from level of antennal fossae, much longer than broad; head index about 0.80; head contraction index about 0.82; sides of head nearly straight; posterior margin weakly convex, postero-lateral corners shortly rounded. Mandibles (pl. 16, fig. 2) considerably shorter than head, weakly but evenly convex, tips only slightly incurved, head-mandible index about 0.80; teeth in outer one-third of mandible, slender, proximally directed, like the barb of a hook. Antennae very slender, of 15 segments, light yellow throughout; gula gradually but deeply contracted in the middle, gula contraction index less than 0.70.

Measurements in Millimeters, and Indices, of Two Soldiers of *Amitermes ensifer* n. sp.

	A	B
Head length	1.44	1.52
Minimum head width	1.01	1.05
Maximum head width	1.14	1.14
Distance between antero-lateral corners of head capsule	....	.88
Mandible length	1.34	1.28
Gular length	....	0.76
Maximum gular breadth	....	0.40
Minimum gular breadth	....	0.26
Pronotum width	0.75	0.74
Head index	0.79	0.75
Head contraction index	0.89	0.92
Head contraction index using distance between corners of capsule as minimum width	....	0.77
Head-mandible index	0.93	0.84
Gular contraction index	....	0.65

Mandible length used in deriving mandible curvature Index II, 1.28
Minimum mandible curvature, 0.11
Mandible curvature index II, 0.86

Worker.—Medium sized, generally light, abdomen gray-black due to contents. Head (pl. 18, fig. 1) very pale yellow; antennae very short, nymph-like, faintly yellowed distally. Clypeus long, as long as labrum, nearly as long as wide at base, sides converging but straight.

Measurements in Millimeters of Five Workers of *Amitermes ensifer* n. sp.

	Minimum	Maximum	Average
Head length	0.93	0.95	0.94
Head width	1.05	1.11	1.08
Pronotum width	0.59	0.67	0.63

Biology and distribution.—This species was taken but once, at Jala, some 21 kilometers west of Colima, where it was attacking a partly decayed tie in the main track of the National Railways.

Amitermes californicus Banks

Plate 17, figures 3 and 4

This species was taken at Presidio, near Mazatlan, and several times in Colima and at Jala and Madrid, lower, dryer localities, respectively 21 and 28 kilometers west of Colima. The soldiers of all these colonies showed smaller heads and in general lighter and less massive mandibles than are characteristic for the species in California. The mandibles of the soldiers taken at Mazatlan were in certain cases longer, much more slender, and with the tooth directed anteriorly.

So striking was this difference (see pl. 17, figs. 3 and 4) that at first I believed it to be a new species. Soldiers in the same colony showed conditions approaching those previously described for the species and a similar tendency toward variation in this direction was noted among the soldiers collected at Colima and vicinity.

These collections very greatly increase the known range of *A. californicus,* giving it the rather surprising north and south extension of about 1,400 miles. The fact that the species was common at Colima and vicinity, the southernmost region of collection, suggests that its range will be found to extend considerably farther to the south.

The biology of the species in the southern range also presents points of considerable interest. First, it was found to be of some economic importance. In Colima it was found in several instances building hard, earthen runways and broad galleries over the exposed walls of stores and storehouses and evidently attacking the wood to some extent. In these situations it was often associated with a new species of yellow-headed nasute, *Nasutitermes* (*Subulitermes*) sp. Questioned as to the amount of damage done, certain merchants pointed out that it made a nuisance of itself by building its structures over goods resting against the walls, particularly dry goods. The dirt thus cemented to the goods could not be entirely removed, save by washing, as the proprietors demonstrated to me.

At Jala, not far to the west of Colima, this species was found attacking several ties in the main line of the National Railways. This is interesting since authentic cases of termite attack on ties in the western hemisphere are rare. The ties attacked were old and in bad condition. How much of this deterioration was due to the termite is problematical. They lined their workings in many cases with hard black earthen structures similar to those used for covered ways. Many recently removed ties showed termite damage, seemingly, from the nature of the workings, due to this species. It should be pointed out that this line is used but twice a day.

Another surprising thing was to find this species building something in the nature of a nest of hard, compact earth around a stub and the base of a near-by post. The nest was about ten inches high. Inhabiting the center of this stub was a strong colony of *Coptotermes crassus* Snyder. It seems probable that the thick mud structure was a defense against attacks from *Coptotermes.*

LITERATURE CITED

Banks, N.

1918. The termites of Panama and British Guiana. Bull. Am. Mus. Nat. Hist., 38:659–667, plate 1, 2 figs. in text.

Banks, N., and Snyder, T. E.

1920. A revision of the Nearctic termites with notes on biology and geographic distribution. U. S. Nat. Mus. Bull., 108:1–228, plates 1–25, 70 figs. in text.

Emerson, Alfred.

1925. The termites of Kartabo Bartica District, British Guiana. Zoologica, 6:291–459, 71 figs. in text.

Light, S. F.

1930. The California species of the genus *Amitermes* Silvestri (Isoptera). Univ. Calif. Publ. Entom., 5:173–214, plates 10–15, 31 figs. in text.

Silvestri, F.

1923. Descriptiones termitum in Anglorum Guiana. Zoologica, 3:307–321, plates 11–15 in text.

EXPLANATION OF PLATES

PLATE 16

All photomicrographs of mounted heads of soldiers of Mexican species of *Amitermes* Silvestri in dorsal view. All × 29.

Fig. 1. *Amitermes grandis,* n. sp.

Fig. 2. *Amitermes ensifer* n. sp.

Fig. 3. *Amitermes cryptodon,* n. sp.

Fig. 4. *Amitermes grandis* n. sp., smaller soldier

Fig. 5. *Amitermes nigriceps* n. sp.

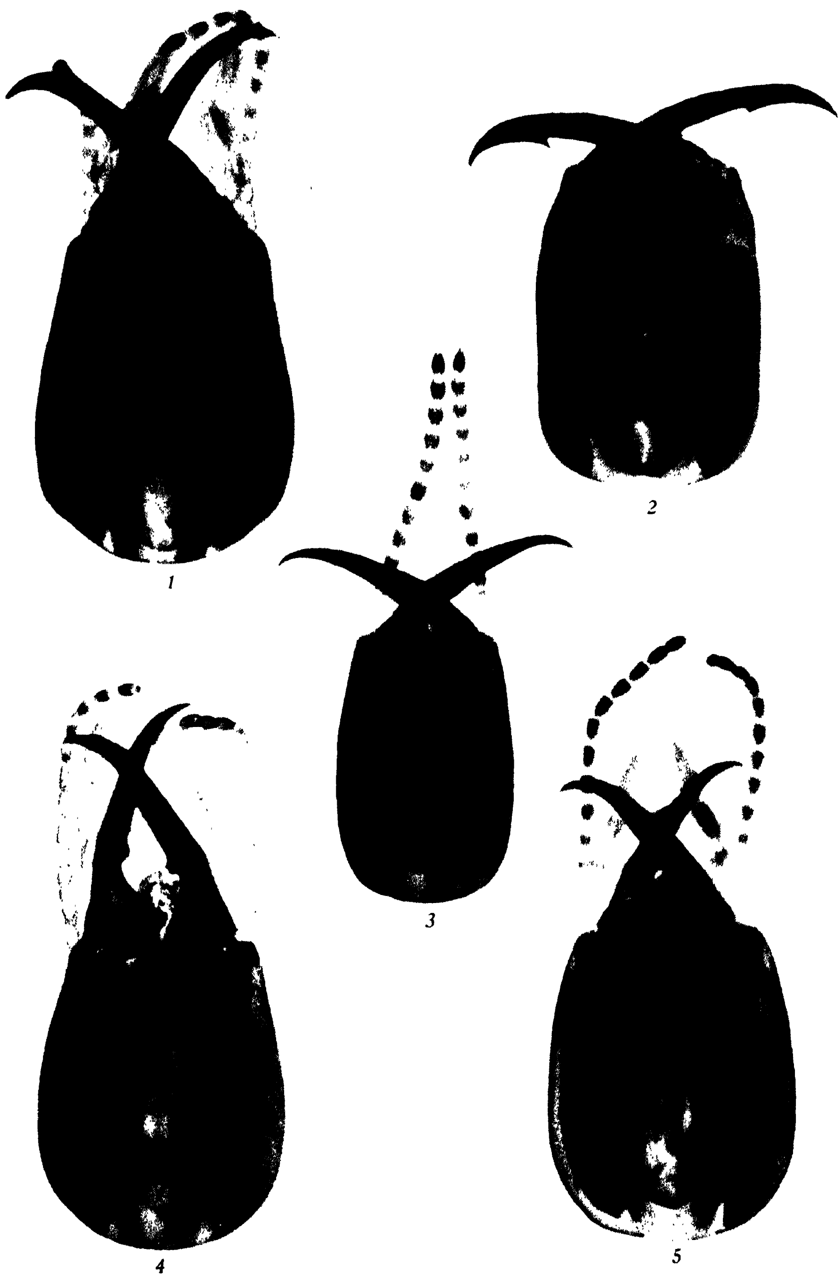


PLATE 17

Photomicrographs of mandibles of various American species of *Amitermes* Silvestri. All ca. × 31.

Fig. 1. *Amitermes grandis*, n sp.

Fig. 2. *Amitermes arizonensis* Banks.

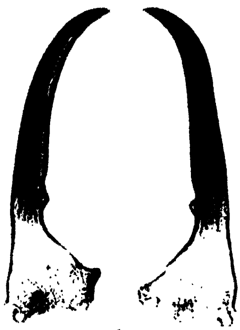
Fig 3. *Amitermes californicus* Banks, short, heavy type common in California.

Fig 4. *Amitermes californicus* Banks, longer, slender type common in colonies from west coast of Mexico.

Fig. 5. *Amitermes modius* Banks.

Fig. 6. *Amitermes beaumonti* Banks.

Fig. 7. *Amitermes cryptodon* n. sp.



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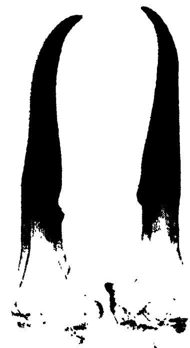

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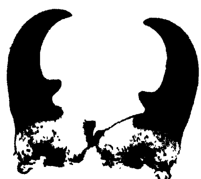

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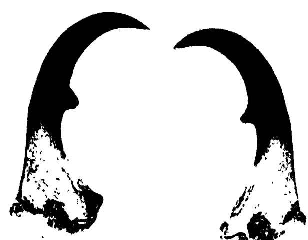

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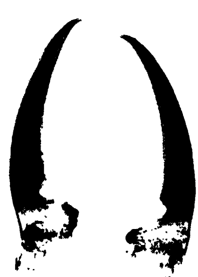

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PLATE 18

Photomicrographs of mounted heads of workers of Mexican species of *Amitermes* Silvestri. All × 29.

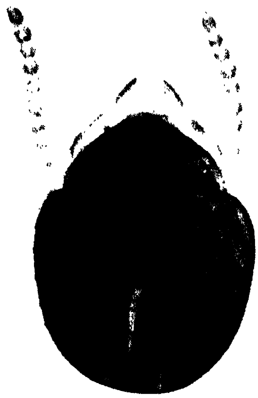
Fig. 1. *Amitermes ensifer* n. sp.

Fig. 2. *Amitermes nigriceps* n. sp.

Fig. 3. *Amitermes cryptodon* n. sp.

Fig. 4. *Amitermes grandis* n. sp.

Fig. 5. *Amitermes arizonensis* Banks.



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A REVISION OF THE GENUS DIVERSINERVUS SILVESTRI, ENCYRTID PARASITES OF COCCIDS (HYMENOPTERA)[1]

BY

HAROLD COMPERE

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Diversinervus Silvestri

Diversinervus Silvestri, Boll. Lab. Zool. Portici, 9:301. 1914.
Cheiloneuroides Girault, Mem. Queensland Mus., 4:96. 1915.
Cheiloneurus (in part) Motschulsky, Boll. Soc. Imp. Natur., Moscow, 36:52, pl. 2, fig. 9. 1863.

The genus *Diversinervus* was erected by Dr. Silvestri, in 1914, for the single species *elegans*, reared from *Saissetia oleae* (Bernard), collected at Nefasit, Eritrea. Girault, in 1915, overlooked Silvestri's *Diversinervus* and described the new genus *Cheiloneuroides* for a species collected in Queensland, Australia. Subsequently, Girault recognized *Diversinervus* and made his genus a synonym. In this paper the species described by Girault, *D. bicristatus*, is recognized as a synonym of the genotype, *D. elegans*. In 1916, Dr. James Waterston described the species *D. silvestrii* from specimens reared from *Coccus viridis* (Green), infesting coffee on the Island of Mauritius. Mr. P. H. Timberlake has shown me a manuscript note made by J. C. Crawford, who examined the types of *Cheiloneurus paradisicus* Motschulsky.

---

[1] Paper No. 235 University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

Crawford's note refers to generic characters which rather clearly indicate that the species is a *Diversinervus*. His notes do not enable recognition of the species nor do I have access to the original description, consequently the species is not included in this paper. Motschulsky's specimens were reared from *Saissetia hemisphaerica* (Targ.), infesting coffee, on the Island of Ceylon.

In this paper three new species are described, a key for the separation of the species is given, and a brief biological note on the biology of *D. elegans* is included. Heretofore *Diversinervus* was thought to be a genus of hyperparasites due to the close relationship of this genus to *Cheiloneurus*, the latter so far as known a genus of hyperparasites.

KEY TO THE SPECIES OF *Diversinervus*, FEMALES[2]

1. Basitarsus of hind legs whitish or yellowish 2
   Basitarsus of hind legs partly, if not completely, blackish 4
2. Mesoscutar and scutellar tufts well developed. Scape more than twice as long as wide 3
   Mesoscutar and scutellar tufts composed of short, sparse setae about twice as long as the adjacent, scattered setae, as shown in figure 1*b*. Scape widely expanded, exclusive of the radical joint, plainly less than twice as long as wide. Club as long as the funicle joints united .... Natal 1, *scutatus* n. sp.
3. Setae of the mesoscutar and scutellar tufts arranged in compact groups about as shown in figure 2*a*. Basal, ventral part of the scape blackish. Dorsum of pedicel blackish. First four funicle joints and apical two club joints fuscous or dark brown. Fifth and sixth funicle joints and basal club joint yellow. Club about as long as the preceding four funicle joints united .... Natal 2, *meridionalis* n. sp.
   Setae of the mesoscutar and scutellar tufts longitudinally arranged (as shown by Waterston's figure). Antennae yellowish or colorless except for a faint browning on the apical club joint, dorsal margin of pedicel and ventral margin of scape. Club as long as the preceding five and one-half joints united. Marginal fringe of the forewings longer than in the foregoing species[3] .... Mauritius 3, *silvestrii* Waterston
4. A dark metallic species, only the center of the mesoscutum, axillae, and the sides of the scutellum ferruginous .... Eritrea 4, *de santisi* n. sp.
   A yellow species which, aside from the mesoscutar and promotal bands, has only the basal half of the abdomen, sides of propodeum, and mesopleura posteriorly more or less dark metallic .... Eritrea, Natal, Queensland 5, *elegans* Silvestri.

[2] *Diversinervus paradisicus* (Motschulsky) is not included and it is possible that one of the species accepted as valid in this paper may be a synonym.

[3] In the original description, Bull. Ent. Res. 7(2):127–140, figs. 1–2, 1916, the ocellar triangle is described as obtuse. If this is not an error, then the species can be easily recognized as all the other species have the ocelli arranged in an acute triangle.

KEY TO THE SPECIES OF *Diversinervus*, MALES

1. Femora and tibiae of hind legs distinctly marked with fuscous 2
   Femora and tibiae of hind legs entirely whitish or the latter slightly fuscous towards the base of the dorsal margin ....*elegans* Silvestri
2. Femora and tibiae of hind legs more or less extensively whitish or yellowish 3
   Femora and tibiae of hind legs predominantly black or dark brown, only the basal end of the former and both ends of the latter narrowly marked with whitish ....*de santisi*, n. sp.
3. Distal end of the hind femora whitish 4
   Distal two-thirds or so of the hind femora fuscous, metallic, the basal part whitish. The distal one-half or more and the basal end of the hind tibiae whitish, the intermediate part fuscous. Middle tibiae faintly marked with brownish near the pale basal annulus which is faintly indicated. Middle coxae more or less fuscous. Remainder of the legs whitish ....*scutatus* n. sp.
4. Hind femora whitish on the ends, the intermediate parts fuscous. Hind tibiae whitish at the base and on the distal one-fourth or so, the intermediate part fuscous. In the single, slide mounted specimen at hand, the middle tibiae appear entirely whitish ....*meridionalis* n. sp.

The males of neither *D. paradisicus* (Motschulsky) nor *D. silvestrii* are known. So far as can be observed the males of the three species described as new in this paper and those of *D. elegans* Silvestri are remarkably alike, differing principally in the color of the legs. The male of *D. elegans* as figured by Silvestri will serve equally well to illustrate the other species. The general color is bluish or greenish black. Face and cheeks more intensively bluish or greenish. Abdomen more predominantly black. Pedicel of antennae more or less fuscous, the remainder whitish or yellowish in parts with variable fuscous markings which are described.

Diversinervus scutatus n. sp.

Figure 1 *a–c*

This species can be distinguished by the widely expanded scape, large club, small setae of the tufts and their long drawn out arrangement. The description is from balsam mounted specimens.

FEMALE—

Frontovertex very narrow, orbits parallel for the greater part. Ocelli in an acute triangle, the anterior ocellus almost its own diameter from the orbits, the posterior pair slightly more than their own diameter from the occiput and almost one-half their own diameter from the orbits. Four rows of small setigerous punctures extend from the anterior ocellus to the frontal ledge where they scatter.

Scape widely expanded, slightly more than one and one-half times as long as wide. Pedicel a trifle less than twice as long as wide. First funicle joint a trifle longer than wide, the second and third about as wide as long, the succeeding plainly wider than long so that the sixth is almost twice as wide as long. Club large, almost as long as the funicle joints united and about one and one-half times as wide as the preceding joint. Other details of antennae as shown in figure 1*a*.

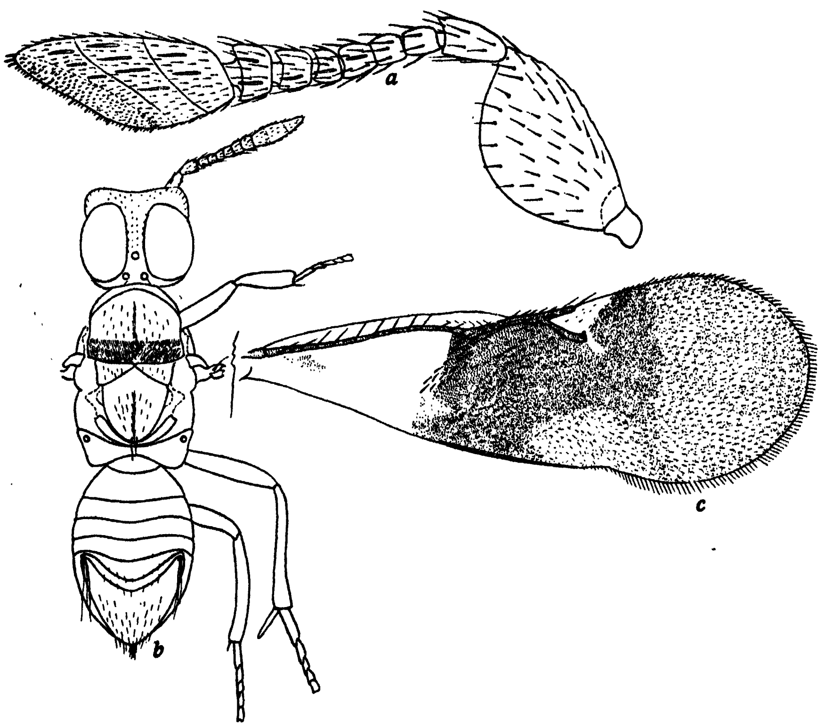

Fig. 1. *Diversinervus scutatus* n. sp. Female. *a*, Antenna; *b*, head and body; *c*, forewing.

Forewings as shown in figure 1*c*. In some specimens the apex of the wing is almost or completely hyaline. Hind wings with the small, fuscous cloud common to the other species.

Vertex with short, erect, black setae, as in the other species. Mesoscutar tuft composed of rather small setae longitudinally arranged. The metallic band occupying the posterior one-third of the mesoscutum clothed with numerous, silvery setae. Each axilla with five or six, short, black setae. Scutellar tuft composed of small setae longitudinally placed. The usual pair of erect, long setae at the apex of scutellum. Other details as shown in figure 1*b*.

It is difficult to determine the exact color from the balsam mounted specimens. Most of the ventral expansion and the base of the scape and the radical joint are blackish, the apex of scape white, and the

remainder yellow. Dorsal half of the pedicel black, ventral half white. The blackish color of the funicle is variable, usually the first four joints are definitely fuscous except for the dorsal and ventral margins which may be pale. In some specimens the fuscous is present on the fourth joint and more rarely on the fifth and sixth joints, but the prevailing color of the distal two funicle joints is yellow. Two basal club joints yellow, the oblique, apical joint blackish. Face yellow, the frontovertex and frontal ledge washed with dark metallic with violaceous reflections. Posterior one-third of mesoscutum with a dark metallic cross band, presumably bluish green but this does not appear to advantage in balsam. In balsam, the anterior one-fourth or so of the mesoscutum appears translucent and colorless without yellow pigment, probably indicative of the band which appears silvery white in tag mounted specimens. Remainder of the thorax yellow with dusky or blackish suffusions as follows: tegulae, a small spot on either side of the scutellum, declivous sides of propodeum and posterior part of mesopleura. These parts described as fuscous or dusky undoubtedly have bright color reflections. Dorsum of abdomen mostly dark metallic, more intense on the first tergite, becoming yellow laterally and at the apex. Exserted ovipositor sheaths yellow. All coxae and most of the femora white. Middle femora with a fuscous spot near the apex. Middle tibiae tipped at extreme base with blackish followed by a white annulus and this by a narrow, dusky blotch or annulus, the remainder pale yellow. The femora and tibiae of the fore and hind legs are marked somewhat similarly to those of the middle pair except that the fuscous areas are not as distinctly marked and are more extensive, in some specimens appearing as faint indefinite suffusions. All tarsi whitish to pale yellow concolorous with the distal ends of the tibiae.

Length.—2.1 mm.

MALE. As described in the key.

Described from thirteen females and fourteen males (holotype, allotype, and paratypes) reared by E. W. Rust, from *Ceronema* sp. on *Ampelopsis*, collected at Durban, Natal, September 7–8 and November 5, 1926. Rust's No. M 12.

Diversinervus meridionalis n. sp.

Figure 2 *a–c*

In this species the scape is more than twice as long as wide, pedicel almost three times as long as wide; club length equal to that of the preceding four funicle joints. It is most readily separated from *D. elegans* by the white basitarsus of the hind legs, from *D. scutatus* by the longer and more compact tufts, from *D. de santisi* by color, from *D. silvestrii* by color and arrangement of the setae composing the tufts.

Female—

Head about like that of *D. scutatus* and *D. elegans.* Scape expanded below, probably wider than as shown in figure 2*b* since the specimen was in a slightly oblique position. Pedicel about two and one-half times as long as wide. First four funicle joints subequal, each about as long as wide, the fifth and sixth appreciably larger, the latter about one and one-half times as wide as long. Club about one and one-half times as long as the sixth funicle joint and as long as the four joints preceding united. Other details of antenna as shown in figure 2*b*.

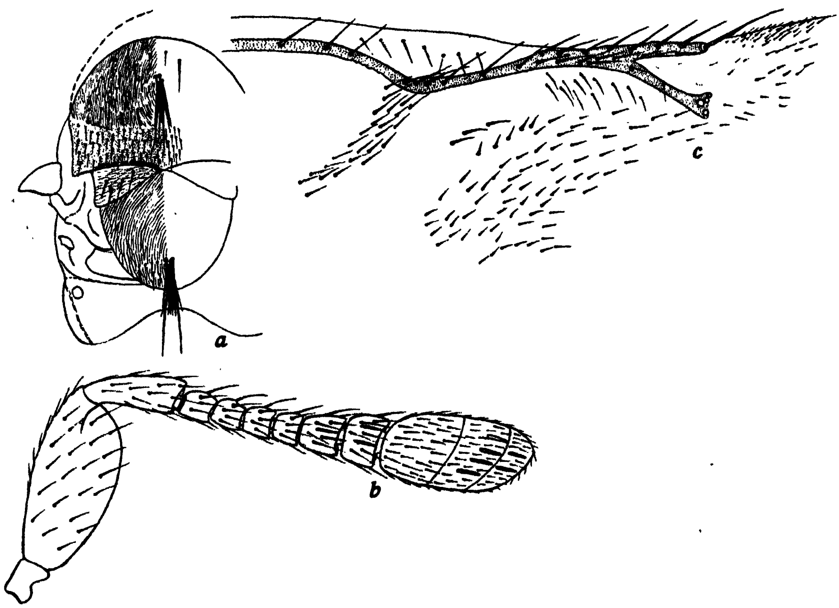

Fig. 2. *Diversinervus meridionalis* n. sp. Female. *a*, Thorax; *b*, antenna; *c*, detail of venation and adjacent cilia.

The forewings are essentially like those of *D. scutatus* n. sp., as shown in figure 1*c*, except that the basal cloud is more extensive, similar to that of *D. silvestrii*, as figured by Waterston, and the apical area is plainly infuscated. Submarginal vein with nine setae.

Vestiture of the thorax about as shown in figure 2*a*. The scutellar tuft is composed of two, close, parallel rows of nine stiff, suberect, black setae and the usual longer, erect, apical pair. The setae of the mesoscutar tuft are grouped closer together than are those of the scutellar tuft. Figure 2*a* does not show the actual number of setae composing the tufts.

Color similar to that of *D. scutatus* n. sp. except that the yellow pigment is more dominant. Abdomen mostly yellow only the first tergite distinctly metallic and the sides anterior to the vibrissal plates slightly dusky. Middle and hind tibiae with a narrow, white annulus at basal ends followed by fuscous suffusions which blend to yellowish. The distal end of the hind tibiae is pale yellow more in contrast than

in the middle tibiae. Knees of the middle and hind legs blackish. Middle femora with a faint fuscous spot or band on the distal one-fourth. Scape blackish on the ventral margin and more broadly towards the base. Apical half of the pedicel blackish, the ventral half white or pale yellow. First four funicle joints fuscous or brown with the dorsal margin pale, slightly yellowish. Fifth and sixth funicle joints yellow. Basal club joint yellow, the apical two joints fuscous. Head and thorax predominantly yellow. Posterior one-third or so of the mesoscutum transversed by a bluish black band, in life, probably silvery. In the balsam mounts the silvery sheen of the pronotal band is destroyed and the derm appears transparent where it overlaps the fuscous concealed part of the mesoscutum. Sides of propodeum and the mesopleura dark metallic.

Length.—1.8 mm.

MALE. As described in the key.

Described from five females and two males (holotype, allotype, and paratypes) reared by E. W. Rust from a *Ceroplastes* sp. collected at Durban, Natal, April 20–26 and May 21–29, 1926. Rust's No. M 19.

Diversinervus silvestrii Waterston

Diversinervus silvestrii Waterston, Bull. Ent. Res. 7(2):127–140, figs. 1–2, 1916.

Waterston's detailed description and the excellent drawings by Terzi will enable recognition of this species.

Diversinervus de santisi n. sp.

This species is more extensively dark metallic than are any of the others and can be recognized at a glance.

FEMALE—

Frontovertex very narrow, hardly as wide as three times the diameter of the anterior ocellus. Ocelli in an acute triangle, the posterior pair separated from each other by about once their own diameter and slightly more than one-half their own diameter from the occipital margin and placed very close to the orbits. The longitudinal rows of setigerous punctures, anterior to the median ocellus, very faint.

Scape slightly less than three times as long as wide. Pedicel slightly more than twice as long as wide. Funicle joints gradually, successively increase in width so that the sixth is about one and one-half times as wide as long. Club large, about as long as the funicle joints combined.

Forewings more darkly infuscated than are those of the other species, although in general the pattern is similar. Hind wings with the infuscated spot common to the other species.

Mesoscutar and scutellar tufts compact, composed of thick, black setae. A pair of erect setae longer than the tuft at apex of scutellum. Eyes with sparse, fine, whitish pubescence. Posterior half of the mesoscutum, narrowly on the sides and the anterior part blackish, metallic, the former strongly bluish, appearing as a transverse cross band set with silvery setae. On either side of the tuft the mesoscutum is blotched with orange or yellowish. Collar of pronotum faintly silvery. Axillae orange yellow with a variable fuscous suffusion. Scutellum mostly orange yellow, the sides and more widely opposite the tuft blackish. Sides of propodeum iridescent with greenish reflections predominating. Abdomen black, metallic with reflections. Tegulae fuscous. Frontovertex and cheeks dark brown, strongly metallic, face light brown. Mesopleura pale brown and translucent anteriorly blending to dark violaceous posteriorly. Lateral and under parts of thorax more or less brownish or fuscous. Fore and hind coxae and trochanters white, those of middle legs dark brown or blackish. Middle femora mostly white on the basal half and straw colored at apex, the intermediate part blackish or dark brown. Hind femora blackish. Middle femora mostly dark brown or blackish, the ends pale. Middle tibiae with a white annulus at base and straw colored on the apical one-third, the intermediate portion blackish or dark brown. Hind tibiae marked somewhat like the middle pair except that the ends are not as extensively pale. Fore tibiae dark brown, the ends obscurely paler. Basitarsus of hind legs black, the following joints white. Basitarsus of middle legs slightly darker brown than are the following joints. Fore tarsi dark brown. Ventral and dorsal margins of the scape broadly suffused with blackish, the remainder yellowish. Pedicel dark brown on the dorsal half, the remainder yellowish. Funicle joints dark brown, the two distal joints sometimes yellowish. First club joint usually yellow in contrast to the funicle which may have the distal two joints yellow, but owing to the blackish setae they appear fuscous. Apical two club joints dark brown to blackish.

Length.—1.8 mm.

MALE—

Blackish with strong bluish or greenish reflections depending on the light. Mesoscutum with a broad, transverse bluish green, posterior band set with sparse, silvery setae. Frontovertex bronzy, face and cheeks greenish. Mesopleura violaceous. Middle coxae, hind femora, hind tibiae, except the ends of the latter and a suffusion on the basal half of the middle tibiae, distad of the annulus fuscous, the remainder of the legs mostly whitish blending to faintly brownish at the knees and on the basal part of the fore tibiae.

Length.—1.4 mm.

Described from 16 females and 3 males (holotype, allotype, and paratypes) reared from an undetermined species of *Pulvinaria* that commonly infests *Croton macrostachys* at the Abyssinian villages of Giglasciu and Ez'taclesan. These villages are located about 45 kilometers north of Asmara, Eritrea, on the plateau at an elevation of

about 7800 feet. The specimens issued on various days in April and May, 1930. The scales from which the parasites issued had five or more exit holes in their backs.

The species is named after Sr. Michele de Santis, a pioneer of Eritrea, who, at eighty years of age, commenced the study of entomology.

Diversinervus elegans Silvestri

Figure 3, *a, b*

Diversinervus elegans Silvestri, Boll. Lab. Zoll. Portici, 9:303–305, 3 figs. 1914.

Cheiloneuroides bicristatus Girault, Mem. Queensland Mus. 4:96–97. 1915.

With a few minor exceptions specimens of *D. elegans,* reared from *Saissetia oleae* (Bern.) collected in Eritrea, are in agreement with Girault's description of *D. bicristatus.* In Girault's description no mention is made of the silvery, pronotal cross band, the black streak on the dorsal margin of the pedicel, nor the fuscous or brownish appearance of the first five funicle joints. In the collection of P. H. Timberlake is a single specimen, determined by Girault as *D. bicristatus,* bearing the label "On black scale, Brisbane, Queensland, George Compere, August 27, 1900." This specimen is paler than Girault's description indicates the types to be, yet it clearly shows the pronotal cross band, blackish streak on the pedicel, and the dusky funicle. The Brisbane specimen differs from those from Eritrea by being paler or faded, less refringent and having smaller setae composing the tufts. Since no good characters can be observed that will separate the two forms, it is thought that they are specifically alike. The fact that they were discovered in widely remote localities is not considered as grounds for maintaining their separate identity since other black scale parasites of African origin also occur in Australia. This is just another one of those cases where a parasite has been accidentally transported with its host from one country to another. Although we do not have a record of *Saissetia oleae* (Bern.) occurring at Townsville, Queensland, where Girault obtained his type specimens, we do know that it occurs at Brisbane where it is attacked by other parasites of African origin.

In the Rust collection there are thirty-three specimens, mostly reared from *Saissetia perseae* taken at Durban and Mayville, Natal, 1926. No characters can be noted which distinguish them from the Eritrean specimens. In regard to one pair, it is stated that they were

taken in coitus after emerging from a parasite inhabiting a species of *Inglisia.* In regard to the other species of *Diversinervus* reared by Rust, on some of the slide labels it is also stated that they were reared from a parasite inhabiting the coccid but I have recorded the coccid as the host under the supposition that a mistake was made in alleging them to be hyperparasitic. Heretofore *Diversinervus* was supposed to be a genus of hyperparasites but this supposition was not based on biological observations. It is now known that *D. elegans* is a primary parasite and presumably the other species are likewise primary. However, this should be verified before any of the other species are transported from one country to another and colonized.

In April and May, 1930, while in Eritrea investigating the parasites of the black scale, *Saissetia oleae* (Bern.), for the University of California Citrus Experiment Station I obtained living specimens of *D. elegans.* The attempt to transport a colony of live parasites to California was unsuccessful and efforts to obtain this species are being continued. The following notes on the biology of the species were made at Nefasit, Eritrea.

Diversinervus elegans was frequently reared in small numbers from black scale collected at various places on the Asmara Plateau. The species was more abundant in the material collected in the town of Asmara than it was in material collected at Giglasciu and Ez'taclesan. According to my rearings this species ranks about fifth in point of numbers, being exceeded by *Scutellista cyanea* (Motsch.), *Metaphycus lounsburyi* (Howard), *Coccophagus saintebeauvei* Girault, *Coccophagus ochraceus* Howard, and *Coccophagus baldassarii* Compere. However, more rearings over a longer period of time may alter this rating.

Oviposition

Diversinervus elegans attacks about the same sized black scale as does *Metaphycus lounsburyi.* If an opportunity for a selection is offered the parasites first oviposit in the larger mature scales. In the absence of mature scales they readily attack the smaller specimens. The oviposition habits of this parasite are peculiar. By a slow and deliberate antennal inspection the parasite locates the anus through which the ovipositor is inserted. In the vial where the ovipositions were watched two and three parasites often competed for the same host. At first they were wary, shying off at the approach of another. After having made a successful oviposition they became more per-

sistent and would make successive ovipositions without leaving the host or without entirely withdrawing the ovipositor, even though harrassed by others attempting to oviposit through the same opening.

The Eggs

The eggs are of the aeriferous type. They are found on dissection, enclosed in the hind intestine suspended on a long stalk, the end of which is inserted through the anal tissue. As many as twelve eggs

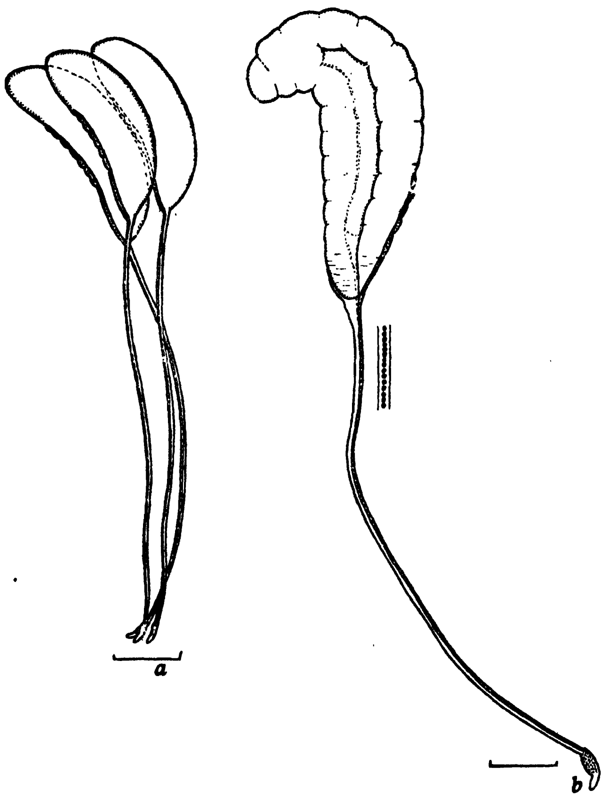

Fig. 3. *Diversinervus elegans* Silvestri. *a*, Cluster of three newly laid eggs; *b*, first stage larva.

were found, packed closely together, in the intestine of one host, presumably the result of several parasites ovipositing. In one case an individual was seen to deposit four eggs in the same scale before withdrawing her ovipositor. A drawing of an egg is shown in figure 3*a*.

A scale oviposited in by *Diversinervus elegans* on May 5 and 6, was dissected on the morning of May 12. In the intestine were six

unhatched eggs, in a late stage of development, and one newly hatched larva. The newly hatched larva is shown in figure 3*b*.

These data were considered sufficient to justify the colonization of the species in the cages for propagation. Several hundred specimens were released in the cages and allowed to oviposit for several weeks prior to the departure for California. It was the intention to complete the life history observations by following the entire larval development before the material was released from the quarantine room and the species colonized in California. En route through the Red Sea, all the material was killed so that the later larval stages of this interesting parasite were not observed.

Taxonomy of the Adults

The original description and illustrations were prepared from three specimens and although they admirably illustrate the general characters there are a few discrepancies which should be explained. I have not seen the type of *D. elegans* and the determination of our specimens is based on the fact that they were reared from the same host as were the types and that these hosts were obtained within 15 miles of Nefasit, the type locality. Also, the differences between the description and our specimens are of a kind that are easily made when a species is described from only several specimens. Silvestri's figure of the antenna of the female does not show the correct shape and proportions of a lateral view, the expansion of the scape is not shown and a narrow aspect of the club is given. The body is obviously copied from a specimen that had been unnaturally expanded by pressure of the cover slip, the abdomen being actually more slender than is shown in his figure.

Female—

Head, dorsal view, apparently similar to that of *D. scutatus* n. sp. as shown in figure 1*b*. Scape only a trifle more than twice as long as wide, not three times as shown in the original figure. Pedicel two and one-half times as long as wide. First three funicle joints each a trifle longer than wide, the fourth and fifth about as long as wide, the sixth wider than long. In general there is no appreciable widening of the funicle before the fifth and sixth joints. Club as long as the four preceding and a portion of the second joint combined and one and one-half times as wide as the distal funicle joint.

The forewings are accurately shown in the original figure.

In our series of specimens the setae composing the mesoscutar and scutellar tufts are much stronger and more compact than is shown in the original figure. This character may be variable or the illustrator, for the sake of clearness, may have desired to show the number

and arrangement of the individual setae in which case they would not appear as a thick, black tuft. In the preceding pages some use has been made of the tufts for diagnostic purposes but this character taken alone is not entirely dependable.

General color yellow. Posterior one-fourth of the mesoscutum marked by a sharply defined, bluish black, metallic cross band set with silvery setae. Posterior margin of the pronotum silvery white, in life or in tag mounted specimens. Sides of propodeum and mesopleura posteriorly more or less dark with metallic reflections. Dorsum and sides on the basal half of the abdomen more or less dark metallic with reflections. Frontovertex and the cheeks just under the eyes slightly brownish with strong metallic reflections. Remainder of head and body straw colored except for traces of brownish or fuscous margining some of the lateral and ventral sclerites. Ventral margin of the scape narrowly margined with blackish. Dorsum of pedicel with a longitudinal black streak. First four or five funicle joints dark brown or fuscous in contrast to the sixth funicle joint and basal club joint which are yellow or straw colored. Two apical club joints blackish or dark brown. Legs marked with whitish as follows: fore and hind coxae and trochanters, basal one-third or so of the fore femora, basal one-half or two-thirds of the middle femora, a narrow annulus near the base of the middle tibiae, both ends of the hind tibiae, three intermediate tarsal joints of the middle legs. Legs marked with fuscous or blackish as follows: basitarsus of hind legs except narrowly at the base which may be whitish, basal end of middle tibiae and a suffusion following the white annulus, hind tibiae with a suffusion following the white at basal end and another suffusion preceding the white apical end, middle femora with a suffusion on the apical one-third following the white and preceding the yellow end, hind femora faintly suffused apically, fore femora on the dorsum of the apical half, fore tibiae faintly towards the base. In some specimens the fuscous markings are faint or absent and the areas mentioned as fuscous may be brownish not contrasting greatly with the remainder of the legs which are yellow or yellowish brown, straw colored.

MALE—

As figured and described by Silvestri and as diagnosed in the key.

Types of new species to be deposited in the United States National Museum.

A DISCUSSION OF THE PARASITES OF SAISSETIA OLEAE (BERN.) COLLECTED IN ERITREA

BY

HAROLD COMPERE

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A DISCUSSION OF THE PARASITES OF SAISSETIA OLEAE (BERN.) COLLECTED IN ERITREA[1]

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INTRODUCTION

The occurrence of the black scale, *Saissetia oleae* (Bern.), in Eritrea was recorded by Silvestri in 1914. Silvestri collected sixty-eight mature scales infesting the wild olive, *Olea chrysophylla,* in the vicinity of Nefasit. Of the scales collected by him fifty-nine were parasitized by chalcids which he described as follows: *Eupelmus saissetiae, Cheiloneurus obscurus, Bothriothorax oleae, Bothriothorax minor, Diversinervus elegans, Scutellista cyanea* var. *obscurata,* and *Tetrastichus* sp. Silvestri stated that the scale was rare at Nefasit and that it would be important to study the biology of these parasites.

[1] Paper No. 236, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

In 1929, I was sent to Eritrea to study the parasites of *S. oleae* for the purpose of importing the effective ones into California. This investigation was undertaken by the University of California Citrus Experiment Station and was under the direction of Harry S. Smith. With the exception of *Eupelmus saissetiae* Silv., a species, presumably of no economic importance, whether primary or secondary, all the species mentioned by Silvestri were obtained. In addition to the species discovered by him ten others were obtained, exclusive of the dark winged form of *Scutellista cyanea* (Motsch.). The particular objective of the trip to Eritrea was to investigate the two species described by Silvestri under the names *Bothriothorax*. These two species, now assigned to the genus *Baeoanusia*, proved to be hyperparasitic. *Diversinervus elegans* Silv. which was suspected to be hyperparasitic proved to be primary. The most effective of the parasites attacking the black scale in Eritrea proved to be species already established in California.

Unfortunately and contrary to what we had reason to suppose, the rarity of the black scale at Nefasit is not entirely owing to parasitic activity. The same aggregation of parasites which parasitize the scale at Nefasit also attack it on the Hamesan Plateau, where severe infestations occur. The rarity of the pest at Nefasit is probably the result of an adverse climatic factor operating in combination with parasitism. Without making a detailed ecological study it is impossible to say whether the pest would flourish at Nefasit if the parasitic influence were excluded. On the Plateau, where the climate is cool and temperate, the black scale flourishes and is subject to about as high a percentage of parasitism as that which occurs at Nefasit. Below Nefasit, in the hot, humid climate of the foothills and lowlands, the black scale does not exist. Nefasit is in a transition zone between a tropical and temperate region.[2]

[2] Eritrea is an Italian Colony on the African coast of the Red Sea. Although located wholly within the tropics Eritrea presents a series of climatic zones, ranging from tropical to subalpine, all within a comparatively short distance. The black scale thrives best in an arid, temperate climate. It is not a pest in tropical regions, if it occurs there at all. The severity of black scale infestations seems to be strongly influenced by humidity. In the arid, warm regions of California the black scale infestations are severe, while in certain temperate regions of Japan, China, Australia, South Africa, where the climate is more humid than that of California, the scale does not rank as a serious pest.

DISCUSSION OF THE INDIVIDUAL PARASITES

Baeoanusia oleae (Silvestri) was one of the most common hyperparasites reared from black scale collected at Asmara, Ez'taclesan, and Giglasciu. Life history studies, made at Nefasit in April, 1930, demonstrated that beyond a doubt this species is an obligatory parasite of *Scutellista cyanea* (Motsch.) and may possibly be monoxenotic. In the collection of the Citrus Experiment Station is a series of specimens collected by Rust in Natal. This species has never been recorded from Cape Colony where extensive collections of black scale have been made. Heretofore, the black scale as well as its best known parasite, *Scutellista cyanea*, were supposed to have originated in the southern part of the African continent. The discovery of the existence of this highly specialized hyperparasite in Eritrea indicates that its host occurred there prior to its establishment in Cape Colony.

Baeoanusia minor (Silvestri) was less common than the foregoing species. Like its congener, it also proved to be hyperparasitic, destroying the larvae and pupae of *Metaphycus lounsburyi* (Howard). Experimentally this species was reared only on *M. lounsburyi* inhabiting black scale. It was taken under circumstances which indicate that it may be parasitic on *Diversinervus elegans* in black scale as well as on *M. lounsburyi.* A single specimen was reared from *Saissetia cuneformis* Leonardi, a rather common coccid, that is attacked by five or more parasites including a species of *Metaphycus*. *Baeoanusia minor* has been known to us for many years under the name *B. africana* Girault. It was reared from material collected by Lounsbury in Cape Town as early as 1903. Rust reared numerous specimens from black scale during his stay in South Africa. There is no record of this species ever having been reared in California from material imported from Africa but it was reared at Sydney, Australia, in 1903, from material sent from Cape Town.

Diversinervus elegans Silvestri, a species heretofore supposed to be hyperparasitic, proved to be a primary parasite of *S. oleae*. It has a peculiar life history. The females oviposit through the anus of the scale and the aeriferous eggs are found in the hind intestine of the host. This parasite was generally distributed but it was not abundant in any one locality. When in Natal, Rust reared a series of specimens that are indistinguishable from the Eritrean species. The species

described by Girault from Queensland, Australia, under the name *Cheiloneuroides bicristatus* is now recognized as a synonym of *D. elegans.* Efforts to import this species into California are being continued.

Cheiloneurus obscurus Silvestri was occasionally reared from black scale collected in Eritrea. This species is supposed to be hyperparasitic although this was not demonstrated to be the case in regard to the species under discussion.

Tetrastichus injuriosus Compere. This is probably the species recorded by Silvestri as *Tetrastichus* sp. It is hyperparasitic on the black scale as well as on other coccids. With one possible exception, this was the most numerous of the hyperparasites reared by me in Eritrea. It also occurs abundantly in South Africa, where the type specimens were collected.

Scutellista cyanea (Motsch.) as well as the variant *obscurata* were obtained. In Eritrea the typical clear winged phase is the common form. In spite of being rather severely attacked by *Baeoanusia oleae, Scutellista* is just about as abundant in Eritrea as it is in California.

Metaphycus lounsburyi (Howard) is probably the most important parasite of the black scale occurring in Eritrea. This species was described from material collected by Lounsbury in Cape Town prior to 1898. It also occurs in Australia where, presumably, it was accidentally introduced with its host prior to 1900. It was purposely imported into California, in 1919, and now holds first rank as an enemy of *S. oleae* in this state.

Coccophagus ochraceus Howard occurs in Eritrea and was frequently reared from the small sized black scale. The history of this species is puzzling. It was originally described in 1887, from specimens reared from a *Lecanium* sp., infesting a native plant in Alameda County, California. It was not again collected in California until 1921 and then it suddenly became quite abundant in southern California at a time when we were endeavoring to import it from Cape Town where it was known to us by the name of *C. bifasciaticorpus.* We had, in fact, colonized African specimens on young black scale in the Whittier, California district, shortly before the true identity of this species was discovered. The sudden rise of *C. ochraceus* to economic value in California cannot be attributed to our liberations of African specimens for it was collected in large numbers from widely separated localities almost simultaneously. Since 1921, *C. ochraceus* has ranked as one of our important black scale parasites, while prior

to that date it remained unknown to us, although great quantities of black scale were collected in California for the purpose of rearing the parasites.

Coccophagus saintebeauvei Girault was extremely numerous in certain restricted areas at Giglasciu and Ez'taclesan, Abyssinian villages, 45 kilometers north of Asmara. The infestations of scale were extremely severe on *Croton macrostachys.* Large numbers of *C. saintebeauvei* were reared from the Giglasciu infestation. Practically all of these parasites issued from material taken from two, isolated trees. The fact that this species was not generally distributed seems to indicate a weakness. The extreme abundance of this species in two, isolated cases can be explained by the fact that it is not uncommon for an isolated infestation of scale to become severe before being located by parasites and then it often happens that the parasite which gets started first becomes more abundant than any of the competing species which arrive later, even though the latter may be more efficient.

Coccophagus saintebeauvei was originally described from specimens reared from *S. oleae* collected at Uganda, September, 1915. It is a primary parasite. The soft "rubber sized" scales are the preferred hosts. The developing larvae avoid the vital organs of the host and entirely complete their pupal development while the host is still alive. Frequently on dissecting a living host the adult *Coccophagus* is found ready to issue and it becomes active the moment it is freed from the membrane which enshrouds it. Fully one-third of the *S. oleae* infesting Crotans at Giglasciu and Ez'taclesan were pure white in color which made it easy to detect the ones occupied by the black colored pupae and adult *Coccophagus.*

Coccophagus baldassarii n. sp. This species is very closely related to *C. anthracinus* Compere, a black scale parasite described from Cape Town, which we have attempted to establish in California. So far as can be observed it differs from the latter species only in the coloration of the legs. Only two specimens are available to serve as types on which to base a description. A few specimens of this species were first obtained from half grown *S. oleae* infesting *Veronia amigdalina* in a garden in Asmara. The fissures in the bark and the pruning wounds on the main limbs partly concealed many, old shells of half grown scales that had been destroyed by this species. The mummified shells had a distinctive appearance so that when similar looking mummies were observed in other localities their destruction was attributed to the work of *C. baldassarii* n. sp. At the time of my visit, March 13

to May 21, 1930, this parasite was not abundant but the parasitized remains discovered on several trees show that it had destroyed an appreciable number of scale. About fifty living adults of this species, including both sexes, were reared. When they were released in the cages they readily propagated in a clean stock of black scale of California origin. Specimens of the second generation were commencing to issue at the time of my departure for California with the material. Although the following description is based on two specimens it is strengthened by the fact that I inspected a number of living specimens before they were released in the cages and that the striking yellow and black coloration of the legs appeared quite constant.

Coccophagus baldassarii n. sp.

FEMALE—

Thorax and abdomen black, except that the parapsides and tegulae are more or less yellowish or orange colored. Face and cheeks yellow with more or less fuscous suffusions. Vertex marked with yellow. Scape concolorous with the face. Sensoria of antennae rather abundant and black thus producing the appearance of a black flagellum. Legs lemon yellow, except the hind tibiae which are almost completely black, only the apical end broadly pale yellow, and the middle and hind coxae, which are more or less dark brown to blackish.

Scutellum with three pairs of setae, each axillae with three rather strong setae. Scutellum about as long as the mesoscutum. Pedicel plainly shorter than the first funicle joint. First funicle joint the longest, the succeeding gradually increasing in width and decreasing in length. Abdomen, in dry tag mounts, about as long as the thorax, rounded at apex. In the two females, tag mounts, available it is not possible to determine the exact length of the ovipositor, but the conformation of the abdomen indicates that it is short, probably extending about one-half the length of the abdomen.

Length.—1.2 mm.

MALE. No males were preserved for museum specimens.

Described from two females (holotype and paratype) the former reared from *Saissetia oleae* (Bern.) infesting marguerites at Asmara, Eritrea, April 9, 1930, and the latter reared from the same host infesting *Croton macrostachys* at Ez'taclesan, April 20, 1930.

Types to be deposited in the United States National Museum.

Named after Dr. L. Baldassari, entomologist of the Colony of Eritrea, who generously cooperated in an effort to make the trip successful.

Euaphycus helvolus (Compere). A form commonly found attacking the small black scales in Eritrea appears indistinguishable from

E. helvolus, a species described from the same host collected in Cape Town, South Africa. This is without much doubt a primary species. It was one of the parasites that successfully reproduced in the cages.

Coccophagus sp. This is described in a paper now in press under the name *C. negritus.* The type specimens were collected by Rust in Natal, where it was recorded from *Saissetia persimile* (Newstead). A dozen or so specimens were reared from *Saissetia cuneformis* collected at Nefasit and at later dates occasional individuals appeared in the jars where the black scale parasites from Giglasciu and Ez'taclesan were being reared. As occasional specimens of *S. cuneformis* were mixed with the *S. oleae* it cannot be positively stated that this species is a black scale parasite. No observations on the life history of this species were made. Adults were released in a cage. It was not necessary to determine in advance of liberation in the cages the exact status of all the species obtained for the scales in the cages were unparasitized, so that primary parasites would be able to reproduce on the scales while hyperparasites would fail for want of a suitable host. As a further safeguard, it was planned to isolate in the quarantine room, at Riverside, all the foreign material until the status of each species was determined beyond any question of doubt.

The acquisition of a large series of *Coccophagus* of the *lecanii* group from Eritrea has not ameliorated the uncertainty already existing in regard to the relationship of the species included in this complex. The rearing records concerning the species under discussion indicate that definite host preferences, if not actual host limitations, exist. The form described as new under the name *Coccophagus eritreaensis* was only definitely reared from *Saissetia cuneformis* and *Coccus hesperidum.* Occasional specimens of this species appeared in the breeding jars where the great bulk of the material consisted of *S. oleae* but in no case were specimens obtained from an unmixed infestation of *S. oleae.* This species was by far the most abundant of the parasites attacking *S. cuneformis* and *C. hesperidum.* Parasites liberated in a cage containing *S. oleae* appeared to oviposit and if it were not for the loss of the material, while en route to California, it would have been determined definitely by the appearance or nonappearance of a second generation whether or not *S. oleae* was a host. If the evidence, which indicates that this species is not parasitic on *S. oleae,* is not misleading, then, it corroborates the suspicion that in the *lecanii* group we are dealing with a number of newly evolved. closely related forms that cannot be satisfactorily recognized on the

basis of the taxonomic characters now used. In a publication now in press, on the classification of the species of *Coccophagus*, the structural characters which distinguish the species of the *lecanii* group are given.

Coccophagus eritreaensis n. sp.

Females—

Structurally and in the coloration of the body not unlike *C. lecanii* and related species. Legs yellow, except for the middle and hind coxae and hind femora which are blackish, the latter yellow at the apex. In my unpublished key to the species of *Coccophagus* this form runs to couplet 35 which does not provide for its reception. The coloration is uniform in the great majority of specimens. Occasional departures from the typical form occur.

Males—

In the key to the males of the species of the *lecanii* group this form runs to couplet 2, which does not provide for it. Legs light, lemon yellow, except the middle and hind coxae and the hind tibiae which are blackish, the ends of the latter yellow. Face and cheeks lemon yellow. Frontovertex fuscous or orange with the ocellar area blackish. Occiput suffused with fuscous. Parapsides yellow with a median fuscous blotch.

Described from twenty females and two males (holotype, allotype, and paratypes) reared from *Saissetia cuneformis* Leonardi and *Coccus hesperidum* Linn. collected at Nefasit and Asmara, Eritrea, at various dates during March, April, and May, 1930. In addition to the specimens selected as types many hundreds of specimens were reared.

Types to be deposited in the United States National Museum.

Coccophagus eleaphilus Silvestri is a species of the *lecanii* group originally described from Nefasit, Eritrea, where it was reared from *Siphoninus finitimus* Silv. A few specimens in agreement with the types of *C. eleaphilus* were reared from cuttings infested with *Saissetia oleae*. Possibly the infestation was mixed with a few specimens of *Saissetia cuneformis* that were not noted at the time so the host record is questionable. It is possible that the specimens identified as *C. eleaphilus* are extreme color departures of *C. eritreaensis* n. sp. If future studies show that *C. eritreaensis* and *C. eleaphilus* are only color variants of the same species, then the specimens with predominantly yellow legs are characteristic of the species and the type specimens, collected by Silvestri, are extreme color departures.

Coccophagus sp. Specimens of an undescribed species were reared, presumably, from *S. oleae* on *Croton macrostachys* collected at Giglasciu. This is a large species closely related to, if not identical with,

a species taken by Rust in Durban, Natal, where he reared them from *Saissetia persimile.* Except for three samples, saved for museum specimens, all others were released in a cage containing unparasitized black scale. As the material was killed before a second generation could develop, it was not determined positively whether this species is a black scale parasite.

Encyrtus sp. A species unlike any of the common better known forms was reared from *S. oleae* collected at Giglasciu and Ez'taclesan. This host record is positive but it was not demonstrated that the species is primary although all evidence indicates that this is the case. Males and females were allowed to mate and were then released in a cage. Day after day for a period of two weeks the females were observed to be busy at work, apparently ovipositing in unparasitized black scale. The press of other work in the final weeks before my departure from Eritrea made it impossible to follow all the species through the egg, larval, and pupal stages. It was planned to continue the life history observations while en route to California and then if necessary, complete the studies in the quarantine room at Riverside. As previously noted, the destruction of all the scales, both parasitized and unparasitized, that were being transported in the Wardian cages, as well as the complete loss of additional material prepared for transit in cold storage, brought all the biological work to an end.

Euxanthellus phillippiae Silvestri. In a preliminary report on the parasites of the black scale under the name *Euxanthellus* sp. we described the oviposition habits of this species and described how the eggs were placed on a primary larvae.[3] The material which we previously reported on was collected in South Africa by Rust. A large series of specimens collected in Eritrea, near the locality where Silvestri obtained his type specimens, are identical with the South African specimens. This is a hyperparasite par excellence. It is entitled to rank as one of the most injurious hyperparasites, fully as harmful as the notorious *Quaylea whittieri* (Girault). It attacks a much wider assortment of hosts than does *Quaylea.* The larvae develop ecto-parasitically on the primary hosts while they inhabit the coccids. Large numbers of *Euxanthellus* were reared from *Saissetia oleae* collected in various localities in Eritrea. Great care should be taken to prevent any of the species of *Euxanthellus* from getting established in California.

[3] Smith, H. S., and Compere, H. Univ. Calif. Publ. Ent. 4(9):264–269, figs. 13–16. 1928.

THE AFRICAN SPECIES OF BAEOANUSIA, AN ENCYRTID GENUS OF HYPERPARASITES (HYMENOPTERA)

BY

HAROLD COMPERE

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BY

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Baeoanusia Girault

Baeoanusia Girault A. A., Mem. Queensland Mus., 4:163. 1915.

The assignment of the species treated in this paper to the genus *Baeoanusia* is based on the supposition that the species *B. africana* Girault was placed in its proper genus by its author.[2] The genus *Baeoanusia* was erected by Girault, in 1915, for the reception of three Australian species. Subsequently he described two other Australian species under *Baeoanusia*. In 1916, Girault described *Baeoanusia africana* from six specimens reared from *Saissetia oleae* (Bernard), collected in Cape Colony, Union of South Africa, by C. P. Lounsbury.

Among the coccid-inhabiting encyrtids collected by E. W. Rust, in South Africa, is a series of specimens that were determined by P. H. Timberlake as *Baeoanusia africana* Girault. These were reared from *Saissetia oleae* collected in Cape Colony. As the specimens agree with Girault's description and are from the type locality and issued from the same coccid it is safe to conclude that the specific determination is correct.

In 1914, Dr. F. Silvestri described *Bothriothorax oleae* and *B. minor* from specimens reared from *Saissetia oleae,* collected at Nefasit,

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[1] Paper No. 237, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

[2] In the following pages this species is shown to be a synonym of *B. minor* (Silvestri).

Eritrea. From Silvestri's description and figures it was evident that the species were not *Bothriothorax* but were possibly *Baeoanusia*. In reply to a request, Dr. Silvestri kindly sent a cotype of his species *Bothriothorax oleae*. It proved to be congeneric with the species identified as *Baeoanusia africana* Girault.

In December of 1929, the Citrus Experiment Station of the University of California sent me to Eritrea, to investigate black scale conditions and to import the primary parasites of the scale into this state. Prior to this investigation it was supposed that the species of *Baeoanusia* were probably primary parasites, and possibly were responsible for the rarity of the black scale at Nefasit, as recorded by Silvestri.[3]

In a large series of specimens collected from various localities in Africa only two species of *Baeoanusia* appear. They are the two species originally described by Silvestri under *Bothriothorax*. The two species are quite distinct and may be separated by the following key:

Frontovertex relatively wide, between one-fourth and one-fifth as wide as the head. Ocelli in an equilateral triangle, the anterior ocellus plainly more than its own diameter from the orbits. Apex of middle tibiae and the spur blackish. Knees of all legs more or less brownish. Tarsi of middle and hind legs whitish. Middle tibiae faintly whitish at base. Remainder of the legs blackish. Abdomen, after shrinkage, longer than the thorax, triangular. A large species measuring about 2.7 mm. in length .... *oleae* (Silvestri)

Frontovertex relatively narrow, about one-eighth as wide as the head. Ocelli in a strongly acute triangle, the anterior ocellus about its own diameter from the orbits. Apex of middle tibiae and the spur yellowish or white. All tibiae broadly marked with yellowish or whitish on the ends. Abdomen, after shrinkage, as long as the thorax, plainly shorter than in the foregoing species. A smaller species measuring about 1.7 mm. in length................................*minor* (Silvestri)

Baeoanusia oleae (Silvestri)

Text figures 1–2

Bothriothorax oleae **Silvestri, Boll. Lab. Zool. Portici, 9:290–291, 2 figs. 1914.**

Many hundreds of specimens of this hyperparasite were reared from black scale, *Saissetia oleae*, mostly collected on *Croton macrostachys*, growing in the vicinity of the Abyssinian villages of Ez'taclesan and Giglasciu, located about 50 kilometers north of Asmara on the Plateau, at an elevation of approximately 7800 feet. Occasional specimens were reared from material collected on various hosts in the towns

[3] Silvestri, F. Boll. Zool. Lab. Portici, 9:258. 1914.

of Asmara and Cheren. From some of the samples taken at Giglasciu, the *B. oleae* outnumbered all the primary parasites combined but these were extreme cases. In the original record concerning this species Silvestri stated that it was the most numerous of the species reared from the black scale which he collected at Nefasit. A series of fifteen females and eight males were reared by Rust as follows: eleven females and six males from *Saissetia persimile* (Newstead), Durban, Natal, February and March, 1927; two females from *Saissetia nigra* (Niet.) Mayville, Natal, May, 1926, and Durban, April, 1926; one female and two males from *Saissetia oleae* (Bern.) Durban, January, 1927, and April, 1926.

As previously stated, it was assumed that this species was probably a primary parasite so that when the first living specimens were obtained they were carefully tended. After being allowed to mate, the specimens were placed in a large vial and provided with unparasitized black scale.[4] They failed to oviposit and more than a week elapsed before the combination of circumstances which stimulated oviposition was discovered.

Oviposition

The female makes a rather rapid examination of the scale by tapping it with her antennae. If the scale is not inhabited by a larva or pupa of *Scutellista cyanea* (Motsch.) the parasite goes to the next scale or sometimes it remains to verify her preliminary inspection by probing the scale with her ovipositor. Evidently, the preliminary inspection with the antennae usually enables the parasite to determine whether or not a suitable host is concealed within the scale. When a scale that contains either a larva or pupa of *Scutellista* is discovered, the parasite proceeds to oviposit. The ovipositor is inserted through the derm on the sides at about the height of the anus. Often, whether the result of chance or of design, the insertion is made through the anus. When the parasite oviposits through the anus the insertion is quickly made through the soft tissue. If the derm is drilled, several minutes elapse before the insertion is made. When drilling in tough derm, the parasite continually vibrates while the hole is being bored. After an opening has been made the parasite exserts her ovipositor its full length and rapidly probes in lateral directions, the body working up and down synchronously with the thrusting of the ovipositor.

[4] These observations on the life history of the species were made at Nefasit, Eritrea, where a temporary laboratory was established.

After observations on the oviposition indicated where to search, the newly laid eggs of the parasites were readily obtained by dissecting the *Scutellista* larvae and pupae. Some of the scales used in the experiments contained larvae or pupae of both *Scutellista cyanea* and *Metaphycus lounsburyi* (Howard). In no case was an egg found in the larvae or pupae of *Metaphycus.*

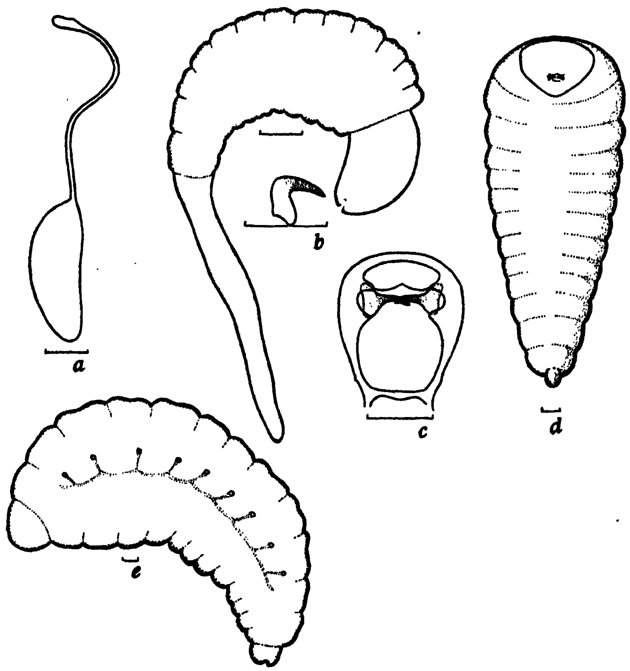

Fig. 1. *Baeoanusia oleae* (Silvestri). *a*, Newly laid egg; *b*, larva at least second stage and its mandible enlarged; *c*, mandibles and endoskeleton; *d*, mature larva ventral view; *e*, mature larva lateral view showing stigmata.

The Eggs and the Larvae

The newly laid egg of *Baeoanusia oleae* has a long stalk as shown in figure 1*a*. The egg, inclusive of the stalk, measures about 1.0 mm. long. The bulbous portion of the egg is 0.35 mm. long by 0.14 mm. wide. The eggs are clear and transparent. Occasionally the stalks get tangled in the internal organs of the host and the eggs do not float out freely in the water when the host is dissected. The exact length of the egg stage was not determined.

In one experiment a female was allowed to oviposit at midday, April 30, 1930. Dissections made on May 4 showed larvae which had

at least reached the second instar as it was necessary to dissect adhering moult skins away to get a clearer view. One of these larvae, at least second instar, and five days old, is shown in figure 1*b*. Thirteen body segments, exclusive of the head and tail, were counted. On May 8, dissections of *Scutellista* belonging to the same lot of material were made. The *Baeoanusia* larvae occupied about two-thirds of the body of the *Scutellista,* yet the latter were still alive. Nine pairs of stigmata were visible and the cast larval skins adhered to the body. Mature larvae were present on May 10 in the lot of material oviposited in on April 30. A ventral and a lateral outline drawing of a mature larva is shown in figure 1*d, e*. In size and shape the *Baeoanusia* larvae are not greatly unlike those of *Scutellista* which they have destroyed. The only remains of the *Scutellista* were the shrivelled skins matted in the débris with hatched scale eggs.

The press of other work prevented a more detailed biological study and the date when the adults issued was not determined.

The Adults

The adults are large, active parasites. All the specimens obtained in Eritrea were of uniformly large size. They appear to be larger than the adult *Scutellista* due to the more compact and stouter structure of the latter.

Silvestri's figure of the adult gives an excellent picture of the general appearance of this species. It is not entirely correct in showing the relative proportions of the frontovertex which varies between one-fourth and one-fifth of the width of the head instead of almost one-third as shown in the figure. Prior to receiving a cotype of the species for study, I supposed the Natal specimens to be undescribed and prepared a description. Since this species is a serious hyperparasite and its further spread is to be guarded against, a description in English is not superfluous.

Female—

Head, dorsal view, menisiform, about twice as wide as long and about four and one-half times as wide as the frontovertex. Frontovertex a trifle more than twice as long as wide (9 : 4). Ocelli about in an equilateral triangle, the posterior pair almost touching the orbits and almost once their own diameter from the occipital margin. The anterior ocellus about one and one-half times its own diameter from the orbits. Head, frontal view, appreciably wider than high (30 : 23). Scrobes well developed, rounded above. Antennal sockets with their upper margins about tangent to the basal ocular line, spaced further

apart than they are from the oral margin. Head, lateral view, dorsal line convex, occipital line slightly concave, facial line almost straight. The eyes reach downward about one-half way.

Mandibles as shown in figure 2*b*.

Antennal scape narrowly flattened and expanded below toward the apex. Pedicel almost twice as long as wide. All funicle joints successively increase in width, the first about as wide as long, the sixth about twice as wide as long. Club about as long as the funicle joints united and almost twice as wide as the sixth, strongly oblique at apex. Other details of the antennae as shown in figure 2*a*.

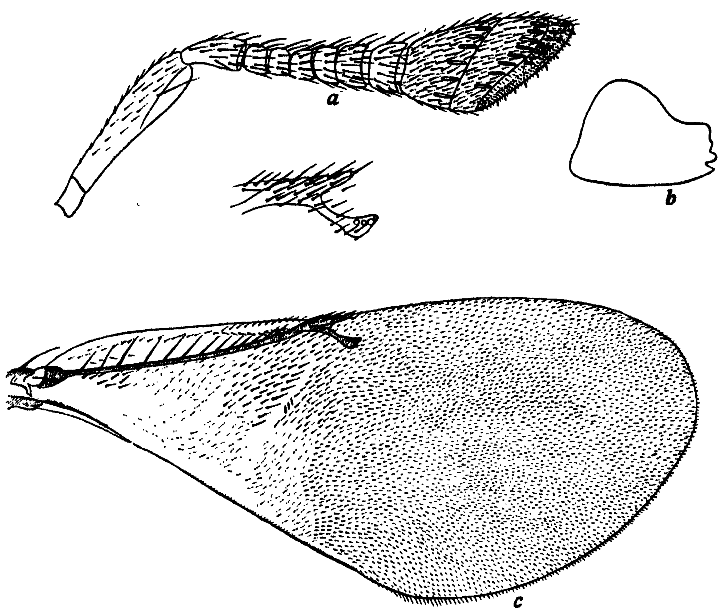

Fig. 2. *Baeoanusia oleae* (Silvestri). Female. *a*, antenna; *b*, mandible; *c*, forewing and detail of venation above.

Fore wings as shown in figure 2*c*. The cilia at the base hardly visible in balsam mounted specimens. Marginal vein about twice as long as wide. Stigmal vein slightly longer than the postmarginal.

Abdomen elongate, triangular, pointed at the apex, the ovipositor sheaths slightly exserted.

Sides of the propodeum with rather conspicuous white setae.

Head finely reticulate except for the polished scrobes. Frontovertex with setigerous punctures arranged in four parallel rows, two submedian rows and a row paralleling each orbit. Mesoscutum and axillae finely, transversely reticulate. Scutellum finely, closely punctate reticulate, the minute aeroles longitudinally arranged. The reticulations of the abdomen somewhat more conspicuous on the iridescent first tergite.

Head dark metallic with reflections, mostly bluish green and violaceous. Scutellum in certain lights almost completely bluish green. Sides of propodeum, mesopleura, and first tergite strongly iridescent

metallic, the former and latter bluish green, the mesopleura bluish green blending with purplish. The remainder of the body shining black. Fifth and sixth funicle joints usually straw colored in contrast to the first four joints which are usually blackish or suffused with brownish. Scape brown or straw colored more or less suffused with fuscous. Pedicel concolorous with the first four funicle joints. Club blackish. Legs mostly blackish. Middle femora with a pale, narrow annulus at base and the apices very slightly pale. Knees of hind legs either blackish or brownish. Knees of fore legs and the tibiae more or less suffused with brownish. Spur of middle tibia blackish. Tarsi white to straw colored, the apical joints faintly brownish.

Length of average sized specimens 2.7 mm.

MALE—

Frontovertex slightly wider than long (6:5). Ocelli in a slightly acute triangle, the posterior pair about one-half their own diameter from the orbits and occipital margin. Antennal sockets at about the center of the face and about their own length apart. Scape short, slightly expanded ventrally towards the apex. Pedicel about as long as wide. The six funicle joints about subequal, each provided with whorls of curved setae. Club solid and about as long as the preceding two joints.

Marginal vein about as long as wide. Cilia of fore wings very fine and hyaline, except for ten or so stronger dark setae marking the edges of part of the speculum.

Antennae brownish or straw colored, the pedicel darker than the remainder. Face and cheeks strongly bluish green and violaceous. Knees of all legs and the apical ends of the fore and middle tibiae brownish to straw colored. Tibial spur of middle legs straw colored. In other respects about like the female.

Length.—1.8 mm.

Baeoanusia minor (Silvestri)

Figure 3

Bothriothorax minor Silvestri, Boll. Lab. Zool., Portici, 9:292–293, 2 figs. 1914.

Baeoanusia africana Girault, Can. Ent., 48(4):114. 1916.

Baeoanusia africana Girault was found to be a synonym when it was discovered that the Eritrean specimens determined as *B. minor* (Silvestri), were in agreement with specimens in the collection from Cape Colony. *B. minor* was supposed to be one of the parasites responsible for the scarcity of the black scale at Nefasit and the discovery of its hyperparasitic character was a disappointment. Prior to the Eritrean investigation this species was known to us only through museum specimens from Cape Town and its synonymy was not suspected. No specimens were ever reared by us in California from

black scale material shipped from South Africa. Rust reared the species in Africa and Froggatt and Gurney reared it in Sydney from black scale sent to Australia by Lounsbury as early as 1903. In the collection of the Department of Entomology, State of New South Wales, are some specimens, said by Mr. Gurney to be in his handwriting, labeled: "Bred from *Lecanium oleae*, from South Africa, from Lounsbury, 23–IX–1903." The specimens from which Girault prepared his description were probably reared many years ago when Lounsbury was collecting black scale for shipment.

Baeoanusia minor was not numerous in any of the samples of black scale collected in Eritrea. The first specimens, one male and four females, issued on May 20, 1930, from scales collected at Asmara and Ez'taclesan. These were confined in a large test tube and provided with unparasitized black scale. The female parasites showed an interest and occasionally one would exsert her ovipositor and cursorily touch a scale with it. The same test was repeated on a number of following days without inducing oviposition. On April 20, a twig of *Ficus dekdekana* infested with black scales, some of which were obviously parasitized was introduced into the vial. At this date the original colony of five specimens had been increased by the addition of others. Oviposition immediately took place, the females selecting parasitized scales. On dissecting the scales that were selected by the parasites for oviposition, eggs were always found in mature, primary larvae, presumably those of *Metaphycus lounsburyi* (Howard). Like its congener, this species is able to detect by the preliminary inspection made with the antennae, whether or not the scale is inhabited. Apparently it only oviposits when the primary larvae are about full grown. When ovipositing the parasite stands on the back of the scale and inserts the ovipositor perpendicularly. Sometimes the parasite spends several minutes in drilling a hole in the derm. Deep insertions and partial withdrawals of the ovipositor enable the parasite to locate the primary larva into which an egg is deposited.

The newly laid egg has a short stalk. The bulbous part of the egg measures 0.25 mm. long by 0.1 mm. wide. An egg is shown in figure 3.

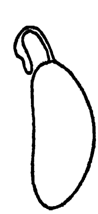

Fig. 3. *Baeoanusia minor* (Silvestri). Newly laid egg.

This note, although meager, established the fact that this species is hyperparasitic and is to be guarded against.

NEW ENCYRTID (HYMENOPTEROUS) PARASITES OF A PSEUDOCOCCUS SPECIES FROM ERITREA[1]

BY

HAROLD COMPERE

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INTRODUCTION

A species of *Pseudococcus,* collected in Eritrea, was determined by both H. Morrison and G. F. Ferris as *citri* (Risso). Although the Eritrean form is indistinguishable taxonomically from California specimens of *P. citri* (Risso), a difference exists and two biological forms of mealybugs are involved under the same name. This is shown by the behavior of *Leptomastix abyssinica* n. sp., an effective parasite of the Eritrean race of *P. citri* which failed to develop in the Californian race of *P. citri.* The parasites freely oviposited in California mealybugs but the eggs were destroyed by phagocytosis.

In the vicinity of Nefasit, Eritrea, small scattered colonies of the mealybugs determined as *P. citri,* were collected on the fruit clusters of the wild olive, *Olea chrysophylla,* during March and April, 1930. As it was evident that the mealybugs were heavily parasitized and as I supposed the species to be *P. citri* at the time, an attempt was made to obtain the parasites for introduction into California. In California, *P. citri* is a pest of minor importance. It occasionally infests certain orchards in San Diego County and it was hoped to correct this situation by the importation of the Eritrean parasites.

[1] Paper No. 241, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

The rarity of *P. citri* in Nefasit is directly attributed to parasitism. No signs of previous heavy infestations were noted and the few small colonies under observation were destroyed by parasites before they had an opportunity to reach injurious numbers. During the latter part of May no live mealybugs could be found. Mummified bodies and cottony secretions adhering to the fruit clusters were evidence that the control was mainly due to the work of natural enemies.

The main purpose of the work in Eritrea was to obtain the parasites of *Saissetia oleae* (Bern.): the investigation of the mealybug parasites was a secondary project to which only spare time could be devoted. As a result, no time was available for life-history studies nor were the different species of parasites given individual treatment. All the mealybug-infested fruits were placed in a large battery jar. Every few days the clusters of mealybug eggs were collected and placed on potato sprouts for the purpose of building up a supplementary supply of hosts for the parasites. Except for two species of *Cheiloneurus*, supposedly hyperparasitic, which were destroyed as fast as they appeared, no special care was given the various parasites which issued from the mealybugs in the battery jar. The mealybugs that had not been parasitized in the field before the collection was made, continued to develop on the olives while in the jar and these served as hosts for a second generation of parasites. By the time the adult parasites of the second generation commenced to issue, practically all the mealybugs in the jar had been attacked. When the adults of the second generation issued there was an excess of parasites and a scarcity of hosts, so in order to maintain the stock it was necessary to destroy the great majority of adult parasites and add unparasitized mealybugs from the supplementary supply that had been separately propagated on potato sprouts. This method of propagating the various parasites in one container was not entirely satisfactory for in the competition for hosts the "intrinsically inferior" parasites were replaced and became relatively scarce, while the "intrinsically superior" species became too numerous.[2]

In addition to the two undetermined species of *Cheiloneurus*, which were destroyed as soon as they appeared, eight species of internal parasites issued from the mealybugs kept in the battery jar. In the following pages three of these species are described as new. The undetermined parasites included two species of *Anagyrus*, one

[2] For an explanation of the terms "intrinsically inferior" and "intrinsically superior" consult Smith, H. S., Bull. Ent. Res., 20(2):141–49 (Aug. 1929).

Pseudaphycus sp., one *Leptomastidea* sp., and representatives of one unrecognized genus of which no museum specimens were preserved. *Leptomastix abyssinica* n. sp. seemed to be the most efficient parasite present for in the jar they multiplied faster than did the other species. With each successive generation the ratio of *L. abyssinica* n. sp. to that of the other parasites increased and as it was the most abundant of the species in the first generation the indications are that it is probably both "intrinsically and extrinsically superior." The two undetermined species of *Anagyrus* ranked next to *L. abyssinica* n. sp. in point of numbers. *Neodiscodes martinii* n. gen and n sp., *Tropidophryne africana* n. gen. and n. sp., *Pseudaphycus* sp., and the individuals of the unrecognized genus were comparatively rare. It can be definitely stated that *L. abyssinica* n. sp. is a primary parasite, as many hundreds were propagated generation after generation on unparasitized mealybugs after the loss of the other species.

In the quarantine room at Riverside, in July and August, 1930, repeated efforts were made to propagate *L. abyssinica* n. sp. on the mealybugs which are of economic importance in California. The parasites freely oviposited in *Pseudococcus citri* (Risso) of California origin, *P. maritimus* Ehrh., *P. gahani* Green, and *Phaenococcus gossypi* (Cockll.), but none of these hosts proved to be susceptible to parasitism by *L. abyssinica* n. sp.

The discovery of effective parasites of a form of *Pseudococcus citri* in Eritrea will be of economic value if the particular biological race which these parasites attack is one injurious to commercial crops in other parts of the world. In the Mediterranean countries, *P. citri* ranks as a serious pest. Whether the Mediterranean race of *P. citri* is the same as the Eritrean or the Californian form is not known.

Leptomastix abyssinica n. sp.

Figure 1

General color black to dark brown with the face, venter of thorax and legs more or less straw colored.

FEMALE—

Head, dorsal view, slightly more than twice as wide as long (17:7); frontovertex slightly wider than long, occupying less than one-half the width of head (7:17). Ocelli in an equilateral triangle, the posterior ocelli about one and one-half times their own diameter from the eye margins and about the same distance from the occipital margin. Head, frontal view, a trifle wider than high (17:15). Eyes

large, protuberant; strongly convergent toward the mouth. Orbits very slightly divergent anteriorly. Antennal sockets large, their base tangent to the basal ocular line. Scrobes short, less than the length of the sockets; a well elevated, strongly convex prominence between the sockets and scrobes. Cheeks very short with a faintly marked genal suture immediately beneath the eyes.

Scape slender, as long as the pedicel and first funicle joint united. Pedicel about twice as long as wide. First funicle joint plainly the longest, more than four times as long as wide, the succeeding joints decrease in length so that the sixth is about twice as long as wide. Club about as long as the sixth and one-half of the fifth funicle joint united, not much thicker than the funicle.

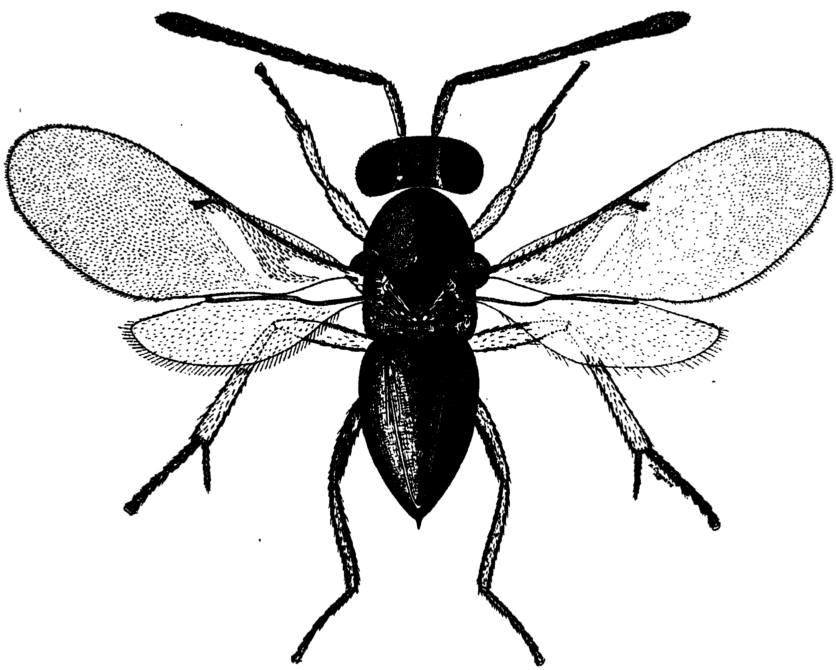

Fig. 1. *Leptomastix abyssinica* n. sp. Female.

Forewings hyaline. The speculum with a cut off basal portion. Cilia of disk fine and dense.

Eyes slightly pilose.

Axillae broadly meeting in a slight carina.

Femora of middle legs only faintly setose in contrast to the tibiae.

Dorsum of head, thorax, and abdomen finely but distinctly reticulated.

Ventral part of scape yellow to light brownish. Frontovertex paralleling the orbits narrowly margined by yellow, straw colored. Face below the sockets, cheeks, mouthparts, and occiput beneath the

foramen light yellow. Ocelli scarlet. Ventral and lateral parts of the prothorax more or less extensively yellow, concolorous with the fore coxae. Apex of scutellum, tegulae, and metanotum more or less yellow to light brown. Legs yellow to brown and fuscous. Fore coxae yellow, middle and hind coxae more or less fuscous or dark brown. Femora and tibiae of fore and middle legs usually predominantly yellow, straw colored, those of hind legs apt to be predominately dark brown to fuscous with variable suffusions of yellow. All tarsi brownish, those of hind legs darker. Spur of middle tibiae brown.

Length.—2.4 mm.

MALE.—In color similar to the female except that the apex of the scutellum is dark and the head more extensively yellow, due to the different conformation. The males of this species are quite similar to the females. The usual sexual differences occur; antennae provided with long curved setae, head thinner fronto-occipitally, the frontovertex wider, abdomen small.

Length.—1.7 mm.

Described from twenty-five females and ten males (holotype, allotype, and paratypes) reared from a *Pseudococcus* taxonomically indistinguishable from *citri* (Risso) collected at Nefasit, Eritrea, March, April and May, 1930.

Tropidophryne n. gen.

Figure 2 *a-d*

A large ectromatine genus easily recognized by the peculiar antennae with five foliaceous, transverse joints, and a solid heart-shaped club. The head is horizontal, face deeply excavated, and the frontal ledge carinated.

FEMALE—

Head, dorsal view, horizontal, plainly wider than long (4:3). Vertex rounded. Eyes mostly dorsal. Frontovertex slightly convex from side to side, narrowest at the posterior ocelli, anteriorly widely expanding to form a projecting ledge arching above the sunken face. Ocelli in an equilateral triangle, the posterior pair about one-half their own diameter from the orbits and about twice their own diameter from the occipital margin; anterior ocellus about twice its own diameter from the orbits. Head, frontal view, much wider than high. Face deeply excavated meeting the frontovertex in a thin, projecting carina. Scrobes not differentiated from the face. Head, lateral view, subtriangular; facial line arcuate below the carina; inclined ventro-caudad. Occipital line straight, inclined strongly ventro-anteriorly. Dorsal line slightly convex.

Mandibles plainly bidentate, the two teeth unequal as in figure 2 *c*. Maxillary palpi four-jointed. Labial palpi three-jointed.

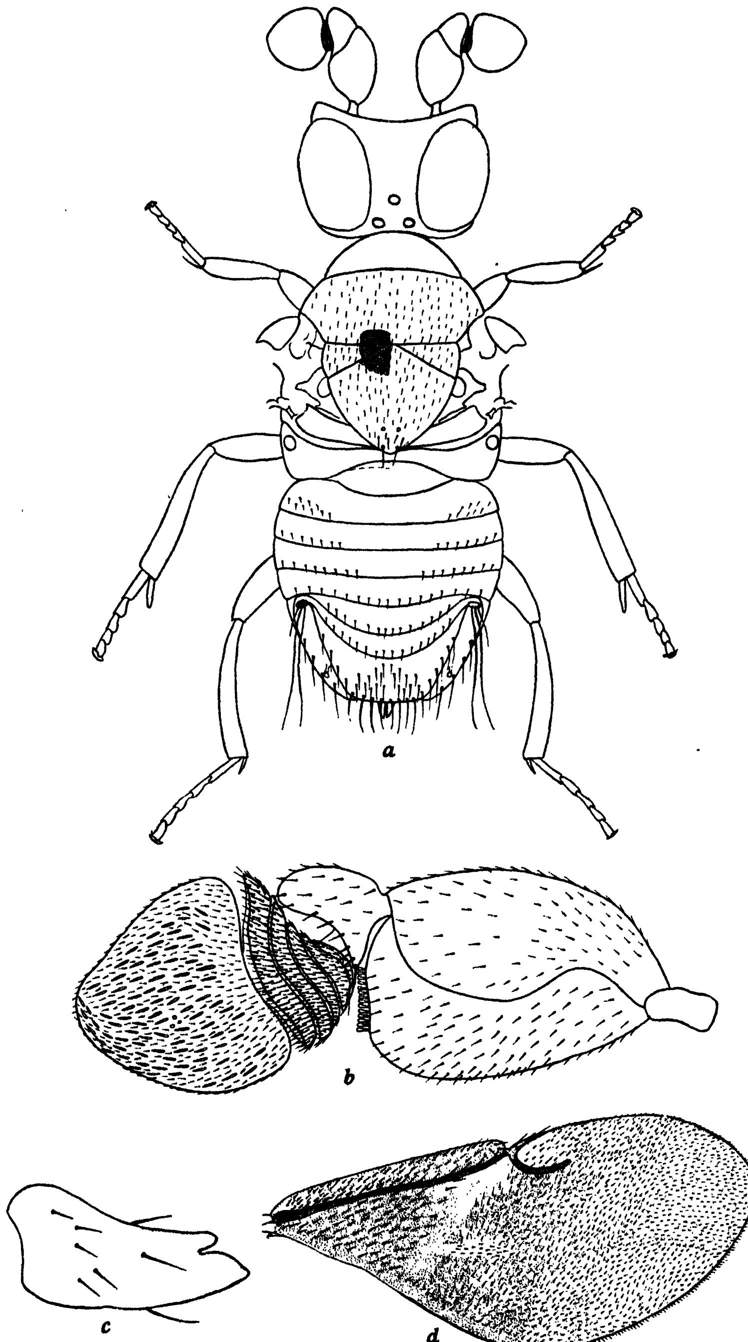

Fig. 2. *Tropidophryne africana* n. gen., n. sp. Female: *a*, adult drawn without showing wings; *b*, antenna; *c*, mandible; *d*, forewing.

Antennae inserted far apart and near the mouth, composed of scape, pedicel, five funicle joints, and solid club. Scape ventrally, widely, laminately expanded and flattened; dorsally folded outward and over with a descending expansion forming a recess into which the flagellum can be partly retracted. Pedicel large, obscurely triangular, the dorsal margin explanate, the inner face concave. Funicle joints very short, strongly foliaceous, successively increasing in width so that the fifth joint is twice as wide as the second; first and second joints not always distinctly separated as the first is small and fits closely. The entire flagellum is concave on the inner side. Club large, cordate, the outer side gently convex, the inner side concave on the basal half, the oblique, apical margin slightly flattened.

Thorax of moderate thickness, wide from side to side. Mesoscutum about two and one-half times as wide as long. Axillae connate. Scutellum about one and one-half times as wide as long, slightly longer than the mesoscutum; the apex angular; the disk slightly convex; the sides narrow and vertical. Metanotum partly concealed by the apex of the scutellum. Propodeum short. Abdomen about as wide and about as long as the thorax. Ovipositor concealed.

Legs moderately short and thick. Tibial spur a trifle shorter than the basitarsus.

Shape and proportions of the head, thorax, and abdomen as shown in figure 2 *a*.

Costal margin of the forewing notched at the termination of the submarginal vein. Marginal vein undeveloped. The stigmal and postmarginal veins form a U, the former slightly the longer and not enlarged at the apex. Marginal fringe short. Forewings generally infuscated as shown in figure 2 *d*. Costal cell of hind wing well developed.

Dorsum of head and thorax punctate reticulate, the aeroles very small giving a shagreened appearance.

Apex of the scutellum furnished with a few small black setae. The setae on the head and thorax appear very fine and inconspicuous in tag mounted specimens under low magnification.

MALE—Unknown.

Genotype.—*Tropidophryne africana* n. sp.

Tropidophryne africana n. sp.

Figure 2 *a-d*

FEMALE—

Collar of pronotum, mesoscutum, axillae, scutellum, and dorsum of the thorax blackish to dark brown. Head, sides, and under parts of the thorax and abdomen mostly, if not entirely, light brown or straw colored, gradually blending with the darker color of the dorsal parts. Antennae dark brown with some fuscous edgings and admixtures of light brown, the latter more pronounced on the sides of the scape. Legs varying from light brown to dark brown but predominantly light colored. The sides of the head, dorsum of the abdomen,

and the darkened punctate areas of the thorax feebly metallic in certain lights. In subdued lights the specimens may appear non-metallic.

Setae of very small size, not as strong and conspicuous as is shown in the figure. The single tag mounted specimen from Eritrea does not show the stronger setae at the apex of the scutellum which are visible in the balsam mounted specimens from Natal.

Length.—2.0 mm.

Described from seven females (holotype and paratypes) reared as follows: six specimens from a *Pseudococcus* sp., reputed to be *P. citri* (Risso), collected at Durban, Natal, by E. W. Rust, March, April, July, 1926; one specimen from a *Pseudococcus* taxonomically indistinguishable from *citri* (Risso) infesting *Olea chrysophylla* collected at Nefasit, Eritrea, April 16, 1930.

Neodiscodes n. gen.

Figure 3 *a-e*

This genus has the facies of *Discodes* Förster, to which it appears most closely related although in many respects it is similar to *Zarhopalus* Ashmead. It is separated from *Discodes* by cephalic characters. In *Discodes* the face is not differentiated from the frontovertex by a change in curvature or sculpture, the head is thinner fronto-occipitally, and the antennae are quite different. Except for the club, which is three-jointed in *Neodiscodes,* the antenna of this species is like that of *Zarhopalus.* The wings and mandibles of the two latter genera are quite similar. *Neodiscodes* differs from *Zarhopalus* by being more robust, the thorax is almost plane instead of moderately convex, the sculpture is coarser and more extensive, and the scobes are not so deeply impressed. Although this form is not greatly unlike *Zarhopalus,* it appears more like *Discodes* when samples of the three genera are viewed side by side.

Female—

Head, menisiform, as wide or a trifle wider than the thorax. In normal position, viewed dorsally, the head appears thin fronto-occipitally, occiput strongly concave, vertex acute. If the head is oriented so as to view the entire frontovertex in a horizontal plane, it appears one and one-half times as wide as long and the frontovertex slightly more than one-fifth as wide as the head and three times as long as wide. Ocelli in an acute triangle. Frontovertex with conspicuous, umbilicate puctures in combination with fine, aerolate reticulations. In profile, the facial line appears almost straight, strongly inclined ventro-caudad. Eyes large, pubescent. The cheeks hardly half the diameter of the eyes. A genal suture defines the face and

cheeks; posterior to this suture the reticulations are striate or in the form of long, drawn out aeroles; anterior to the suture the sculpture on the face, is finely and closely punctate. Face short, the scrobes well defined but not deeply impressed nor polished, reaching upward to the umbilicate punctate area, slightly rounded above.

Antennae, short, the scape expanded below. Pedicel large. All six funicle joints strongly transverse, much wider than long, progressively increasing in size. Club large, three-jointed, longer than the funicle joints united.

Mandibles tridentate, the median tooth the largest, the dorsal tooth small and set far back as shown in figure 3 *b*. Maxillary palpi four-jointed; labial palpi three-jointed.

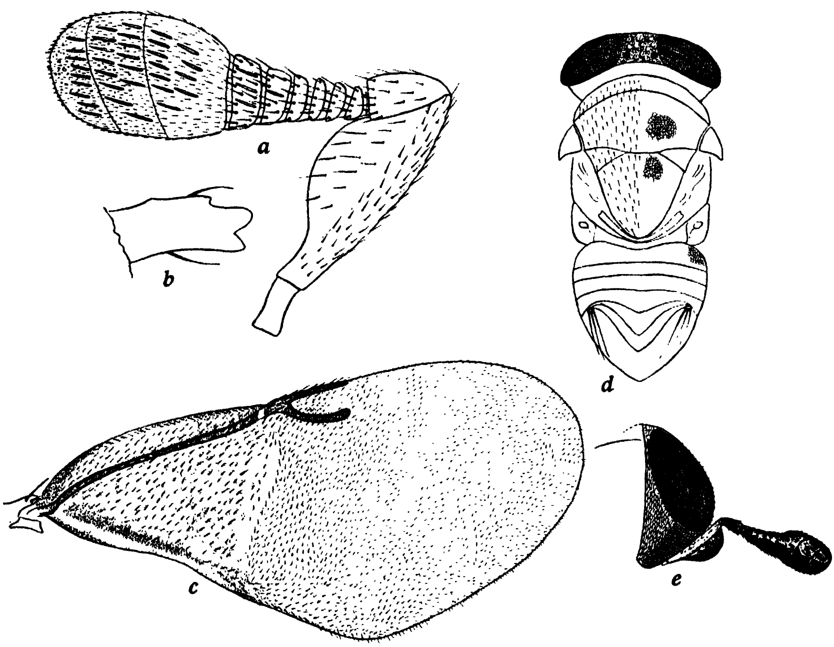

Fig. 3. Neodiscodes martinii n. gen., n. sp. Female: *a*, antenna; *b*, mandible; *c*, forewing; *d*, dorsal view without appendages; *e*, head, lateral view.

Thorax short and robust. Mesoscutum short, twice as wide as long and shorter than the scutellum. Axillae separated, the sutures indistinct. Mesoscutum, axillae, and scutellum almost plane, the surface finely areolate reticulate with scattered, very shallow, weak thimble impressions which only appear in certain lights; uniformly clothed with fine, reclinate setae and the apical curvature of the scutellum on the sides provided with several suberect setae not much stronger than those on the disk. Sides of propodeum, mesopleura, tegulae, and abdomen finely areolate reticulate.

Abdomen, after shrinkage, a trifle shorter than the thorax, triangular. Ovipositor not exserted.

Forewings generally infuscated especially on the basal and central portions, paler toward the apex. Marginal vein about twice as long as wide. Postmarginal and stigmal veins well developed, subequal, the latter not enlarged at the apex as shown in figure 3 *c*.

Genotype.—Neodiscodes martinii n. sp.

Neodiscodes martinii n. sp.

Figure 3 *a-c*

FEMALE—

General color black metallic. Frontovertex, face, and cheeks with strong bluish reflections. Antennae blackish. Dorsum of the thorax black, the sides and under parts more or less suffused with dark brown in parts. Abdomen black to dark brown, more refringent than the thorax. All tarsi light brown, the apical joints fuscous. Middle femora on the distal third or so shading to dark brown, the remainder of the legs black.

Length.—1.6 mm.

Described from three females (holotype and paratypes) reared from *Pseudococcus citri* (Risso) infesting the wild olive, *Olea chrysophylla* at Nefasit, Eritrea, April, 1930.

Types to be deposited in the United States National Museum.

AN ANNOTATED LIST OF THE INSECTS AND ARACHNIDS AFFECTING THE VARIOUS SPECIES OF WALNUTS OR MEMBERS OF THE GENUS JUGLANS LINN.

BY

R. E. BARRETT

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INTRODUCTION

This paper was undertaken for the purpose of bringing before the walnut industry, quarantine officials, and entomologists information on the pests of the genus *Juglans* and especially *Juglans regia* Linn.

At the present time the most serious insect pests of *Juglans regia* in California are *Carpocapsa pomonella* (Linn.), the codling moth; *Chromaphis juglandicola* (Kalt.), European walnut aphis, and *Rhagoletis suavis* subsp. *completa* Cress., the walnut husk maggot. There are other walnut insect pests not yet found in California against which the walnut industry of California should be on its guard. Probably the most serious insect pests not yet introduced are *Conotrachelus juglandis* Lec., the walnut curculio; *Acrobasis nebulella* Riley, pecan leaf case bearer; *Argroplace leucolreta* Meyr., false codling moth; *Acrobasis caryae* Grote, walnut bud moth; and the other species of *Rhagoletis* which work on walnuts.

In this paper the attempt has been made to enumerate systematically all the species of insects and Arachnida which feed on any member of the genus *Juglans,* together with an indication of the type of injury caused. The species of *Juglans* attacked by the insect are

noted, accompanied by the name of the author making the observation. The citation to the literature follows the author's name; the first two numbers are the final figures for the year in which the observation was published; the other number separated by a hyphen, gives the page on which the observation is recorded. Whenever possible citations are made to works giving the most complete account of life-history or control.

The species have been arranged in phylogenetic order to family, but the genera and species have been arranged in alphabetical order as check lists of some of the groups were lacking.

The geographical distribution for each insect is indicated. If the insect has been observed feeding on *Juglans* in Ventura County, California, by the author, or notes of its occurrence on *Juglans* in Ventura County are on file at the insectary of the Saticoy Walnut Growers Association, Ventura County is then noted in the distribution. The natural distribution of the members of the genus *Juglans* is indicated elsewhere in the paper.

Reference to insects working on the genus *Juglans* are scattered throughout entomological literature and the author has undoubtedly overlooked many published notes. No reference is made to insects working on over one-half of the recognized species of *Juglans*. It will therefore be obvious that this paper should be looked upon as a preliminary and very incomplete report.

I wish to acknowledge my indebtedness to Messrs. August Busck, F. R. Cole, E. O. Essig, D. Moulton, E. C. Van Dyke, and many other workers for their kindness in determining specimens. I am also indebted to S. E. Flanders, who formed a preliminary list of insects attacking the genus *Juglans*.

The author desires to acknowledge particularly his indebtedness to Professor E. O. Essig for many helpful suggestions and criticisms.

A BRIEF HISTORY OF WALNUT CULTURE

The Persian or English walnut (*Juglans regia* Linn.) was introduced into western Europe by way of Greece. The tree was first cultivated in Italy with the dawn of the Christian era although prior to this time the nuts coming from Greece and the interior of Asia Minor were an article of commerce in western marts.

The term "walnut" is a corruption of "Gaul nut," the name under which the product of the trees of Gaul, the ancient name of

France, was marketed. It was probably first used by the Germans to designate the product as "the foreign nut."

Although the walnut was probably introduced into cultivation from Persia, it has been found growing in a state of nature in widely separated sections of the mountains of southwestern Asia. Evidences of a wider distribution of this tree, or a very closely related species, are afforded by the fossils of the Tertiary period, which according to M. de Saporta show that it formerly existed in southeastern France.

The Persian or English walnut was first introduced into California about 1769 in the mission gardens. Colonel J. J. Warner in 1843 made the first planting outside the mission gardens. The industry received its start in 1867 when Joseph Sexton planted a grove near Santa Barbara from walnuts which were probably imported from Chile. From this planting near Santa Barbara were selected the commercial varieties grown in southern California.

In the central part of California the development of the walnut varieties has been independent of the southern part of the state. Trees and scions were imported into central California direct from France by Felix Gillet, of Nevada City.

California State Department of agriculture figures for bearing acreage in California are as follows: 1913—13,138 acres; 1928—83,252 acres; 1931—104,000 acres (estimated). In 1929 there were approximately 125,000 acres of walnut trees of all ages within the state.

NATURAL DISTRIBUTION OF THE MEMBERS OF THE GENUS JUGLANS LINN.

Juglans australis Griseb.	Argentina
baccata Linn. (?)	West Indies
californica Wats.	California, south coast region
cinerea Linn.	New Brunswick and Ontario to North Dakota southward to Delaware. In the Alleghanian region south to Georgia and northeastern Mississippi, Arkansas.
cordiformis Max.	Japan
formosana Hayata	Formosa
granatensis Linden	Colombia
hindsii Jepson	Central California
insularis	Cuba, Jamaica
jamaicensis D.C.	Jamaica
major Heller	Western New Mexico
mandshurica Max.	Northern China

Juglans australis Griseb.—(*Continued*)	
mexicana Watson	Mexico
mollis Engelm.	Mexico
nigra Linn.	Massachusetts to southern Ontario, Minnesota, and eastern Kansas and southward to Florida and Texas.
pyriformis Liebm.	Mexico
regia Linn.	Greece eastward through Asia Minor, Transcaucasia, northwestern Himalayan region, northern Burma
rupestris Engelm.	Northern Mexico, Arizona, New Mexico, and the Rio Grande part of Texas
Juglans sachalinensis Komatsu	Sakhalin
sieboldiana Max.	Eastern shore of Asia
stenocarpa Max.	Amur

E. B. Copeland, of the Department of Botany, University of California, under date of April 21, 1930, writes, "There have also been published thirty-one species by Dode, Bull. Coc. Dendr. France, 1909. Among these are probably a number of perfectly valid additional species and others which botanists, less inclined to very fine splitting of species fail to distinguish."

Class ARACHNIDA

Order ARANEAE

TETRANYCHIDAE

Bryobia praetiosa Koch Sap feeder on leaves *J. regia*. Flanders, S.E.	California (Ventura Co.)
Tetranychus telarius (Linn.) Puncture and drain sap from cells of leaves *J.* sp. Essig 26–29	California (Ventura Co.)

ORIBATIDAE

Oribella modestus Banks Under dead bark *J. regia*. Flanders, S.E.	California (Ventura Co.)

TYROGLYPHIDAE

Tyroglyphus farinae De Geer Feed on stored nuts *J. regia*. Flanders, S.E.	North America

ERIOPHYIDAE

Eriophyes caulus Cook Sap feeders on leaves, form galls *J. nigra.* Leonard 28–1077	New York
Eriophyes tristriatus (Nalepa) Sap feeders, form small galls on upper surface of leaves *J.* sp. Essig 26–47	Germany
Eriophyes tristriaus var. *erineus* (Nalepa) Yellow or brownish erineum on upper surface of leaves *J. regia.* Essig 26–47	Argentina, California (Ventura Co.), Oregon
Eriophyes (*Phytoptus*) *vitis* (Landois) Sap feeder *J.* sp. Girardi 22–	Europe, North America, Uruguay
Phyllocoptes unguiculatus Nalepa Sap feeder *J. regia.* Sajo, Chas., correspondent	Europe

CLASS INSECTA

ORTHOPTERA

LOCUSTIDAE

Schistocerca americana Drury Leaf feeder *J.* sp. Howard 94–224	Southwestern states

TETTIGONIIDAE

Microcentrum rhombifolium (Saussure) Eggs observed on twig, feeding not noted *J. regia.* Author	United States

GRYLLIDAE

Oecanthus niveus (DeG.) Wounds twigs with ovipositor in depositing eggs *J. cinerea*, *J.* sp. Parrott and Fulton 13–177	United States

ISOPTERA

KALOTERMITIDAE

Kalotermes hubbardi Banks Honeycombs dead wood *J.* sp. Banks and Snyder 20–137 *J. regia.* Flanders, S.E.	Arizona, California (Ventura Co.), Lower California, New Mexico, Texas

Kalotermes minor (Hagen) Honeycombs dead wood *J.* sp. Essig 26–117	Arizona, California (Ventura Co.), New Mexico
Termopsis angusticollis Hagen Honeycombs dead wood *J. regia.* Author.	California (Ventura Co.), Nevada, Oregon

TERMITIDAE

Leucotermes sp. Injuring young trees planted in newly cleared land by feeding on roots *J.* sp. Snyder 16–18	United States

THYSANOPTERA

THRIPIDAE

Frankliniella occidentalis (Pergande) Feeds on catkins and between nuts. *J. regia.* Author.	Arizona, California (Ventura Co.)
Heliothrips haemorrhoidalis (Bouché) Injures flowers *J. regia.* Porter, C. E. 24–97	Cosmopolitan
Taeniothrips inconsequens (Uzel) Injures flowers *J. regia.* Author. *J.* sp. Moulton 07–54.	British Columbia, California, New York, Ontario, Oregon

PHLOEOTHRIPIDAE

Liothrips ocellatus Hood Inhabits moss and galls *J. nigra.* Watson 23–54.	Illinois, Virginia

HOMOPTERA

CICADIDAE

Tibicina septendecim (Linn.) Injures twigs in egg laying *J.* sp. Hoseman 15–	Eastern states

CERCOPIDAE

Clastoptera obtusa (Say) Sap feeder, on fruit *J. nigra.* Brooks, F. E., correspondent	California, Colorado, New Mexico, Texas, Ohio–Kansas, Quebec–North Carolina

MEMBRACIDAE

Carynota mera (Say) Punctures twigs in egg laying *J. cinerea.* Felt 06–720	Ohio, Ontario, New York, New Jersey, North Carolina, Quebec, Texas
Ceresa bubalus (Fabr.) Punctures twigs in egg laying *J. cinerea.* Funkhouser 17–388	Canada, United States

Ceresa diceros (Say) Punctures twigs in egg laying *J. cinerea.* Funkhouser 17–388	Eastern Canada, United States
Cyrtolobus vau (Say) Punctures twigs and buds *J. cinerea.* Felt 06–717	United States
Enchenopa binotata (Say) Punctures buds *J. cinerea* Felt 06–594 *J. nigra.* Brooks, F. E., correspondent	Canada, Florida, Massachusetts, Michigan, Mississippi, New York, Texas, West Virginia
Stictocephala inermis (Fabr.) Punctures twigs in egg laying *J. cinerea.* Funkhouser 17–388	United States
Telamona unicolor Fitch Taken on foliage *J. cinerea,* J. sp. Funkhouser 17–263	Eastern states

CICADELLIDAE

Empoasca mali (Le Baron) Sap feeder *J. californica.* Essig 15–63	British Columbia, California, Oregon, Washington, Eastern states
Gypona octolineata (Say) Sap feeder *J.* sp. Essig 26–210	Eastern states, Oregon, Ontario, Tennessee
Oncopsis distinctus (Van D.) Sap feeder *J. nigra.* Britton 23–73	Illinois, Ohio, Ontario, Maryland, Missouri, New York, New Jersey, North Carolina, Pennsylvania, Tennessee

APHIDIDAE

Aphis juglandina Walker Sap feeder *J. regia.* Wilson and Vickery 18–258	
Aphis juglandis Blanchard Sap feeder *J. regia.* Wilson and Vickery 18–258	
Callipterus juglandis Goeze Sap feeder *J. regia.* Wilson and Vickery 18–259	
Callipterus juglandis Frisch Sap feeder on upper surface of leaves. *J. regia.* Thompson 29–270 *J.* sp. Theobald 24–	Oregon, Europe, England
Chromaphis juglandicola (Kaltenbach) Sap feeder on under surface of leaves *J. regia.* Davidson 14–3	California (Ventura Co.), Colorado, Oregon, Minnesota, Europe
Kurisakia juglandicola Takahashi Sap feeder *J. sieboldiana.* Takahaski 24–	Japan
Macrosiphum picridis Fab. Sap feeder *J. regia.* Wilson and Vickery 18–259	

Monellia californica Essig Sap feeder on under surface of leaves *J. californica.* Essig 26–233	Southern California (Ventura Co.)
Monellia caryae (Monell) Sap feeder *J. californica.* Swain 19–30 *J. nigra.* Essig 26–233	California, Oregon, Illinois, Michigan, Mississippi, Nebraska
Monellia caryella (Fitch) Sap feeder *J. californica.* Gill 17–33 *J. nigra. J. regia.* Swain 19–30	California (Ventura Co.), Eastern states
Myzus persicae (Sulzer) Sap feeder *J.* sp. Essig 26–253	North America (Ventura Co.)
Schizoneura caryae Fitch Sap feeder *J. nigra.* Felt 06–717	New York

COCCIDAE

Aspidiotus aesculi solus Hunter Sap feeder *J. nigra.* McGillivray 21–414	Kansas
Aspidiotus ancylus (Put.) Sap feeder *J. nigra.* Hollinger 23–9	Colorado, Mississippi, New Mexico, New York, Washington
Aspidiotus camelliae Sign. Sap feeder *J. regia.* Essig 26–313	Arizona, California (Ventura Co.), Colorado, Florida, Missouri, New Mexico, Oregon, West Indies
Aspidiotus forbesi Johnson Sap feeder *J. nigra.* Hollinger 23–11	Eastern states west to Colorado and Northern Mexico
Aspidiotus juglandis Colvée Sap feeder *J. regia.* Lindinger 12–187	Spain
Aspidiotus juglans-regiae Comstock Sap feeder *J. nigra.* Hollinger 23–12 *J. regia.* Essig 26–315	North America (Ventura Co.), Europe
Aspidiotus lataniae Sign. Sap feeder *J.* sp. Merrill and Chaffin 23–203	Southern states, Cuba, Europe
Aspidiotus osborni Newell and Ckll. Sap feeder *J.* sp. Merrill and Chaffin 23–205	California, Florida, Georgia, Iowa, Kansas, Lower California, New York
Aspidiotus perniciosus Comstock Sap feeder *J. regia.* J. sp. Essig 26–315	Cosmopolitan (Ventura Co.)
Aspidiotus ulmi Johns. Sap feeder *J. cinerea, J. nigra.* Hollinger 23–17	Missouri, New York
Aulacaspis pentagona (Targ.) Sap feeder *J.* sp. McGillvray 21–315	New York, West Indies

Chionaspis furfura (Fitch) Sap feeder *J. cinerea, J. nigra.* Hollinger 23–23	Colorado, Eastern states, Idaho, New York, Utah, Canada, England
Chionaspis lintneri Comstock Sap feeder *J. cinerea.* Houser, J. S., correspondent	California, Colorado, Ohio, New York
Chionaspis ortholobis Comstock Sap feeder *J. cinerea.* Essig 26–310	California, Colorado, Massachusetts, Missouri, New Mexico, Nebraska, Ohio, Kansas
Chrysomphalus aurantii (Maskell) Sap sucker on trunk, branches and twigs *J. californica.* Author *J. regia.* Essig 26–318	Australia, Cuba, India, New Zealand, South Africa, Southern Europe, Southern California (Ventura Co.), Southern states
Chrysomphalus corticosus Brain Sap feeder *J. regia.* Lounsbury, Chas. P., correspondent	South Africa
Coccus pseudomagnoliarum (Kuwana) Sap feeder *J. regia.* Quayle, 17–	California, Japan
Diaspis leperii (Sign.) Sap feeder *J.* sp. Green 18–239	Europe
Diaspis pentagona (Targ.) Sap sucker *J.* sp. Merrill and Chaffin 23–232	Cosmopolitan
Diaspis piricola (Del Guerico) Sap sucker, produces depressions in limbs *J. regia.* Batchelor 29–89	
Icerya purchasi Maskell Sap feeder on bark *J. regia.* Essig 26–269	California (Ventura Co.), Arizona, Florida, Mississippi, New York, Australia
Lecanium canadense (Cockerell) Sap feeder *J.* sp. Essig 26–293	United States
Lecanium cerasorum Cockerell Sap feeder *J. regia.* Essig 26–293	California, Japan
Lecanium cockerelli Hunter Sap feeder *J.* sp. Felt 06–725	Kansas, Massachusetts, Nebraska, Ohio
Lecanium corni Bouché Sap feeder on twigs *J.* sp. Merrill and Chaffin 23–261	Europe, United States
Lecanium (*Physokermes*) *coryli* (Linn.) Sap feeder *J. nigra, J. regia.* Lindinger 12–188	Europe

Lecanium excrescens Ferris Sap feeder on twigs *J. regia.* Essig 26–295	California
Lecanium juglandifex Fitch Sapsucker *J. cinerea.* Felt 06–720	New York
Lecanium juglandis (Bouché) Forms galls on twigs *J. regia.* Felt. 06–719	Middle states, Nova Scotia, Canada, France, Germany
Lecanium pruinosum Coquillett Sap feeder on twigs, fruit and leaves *J. regia.* Essig 26–296	Arizona, California (Ventura Co.), New York
Lepidosaphes juglandis (Sign.) Sap feeder *J. cinerea.* McGillivray 21–272	France, Germany
Lepidosaphes multipora (Leonardi) Sap feeder *J.* sp. Green 18–239	
Lepidosaphes ulmi (Linn.) Sap feeder on twigs and branches *J. regia.* Lindinger 12–187 *J. cinerea.* Leonard 28–202 *J. regia.* Essig 26–306	Australia, Canada, Japan, New Zealand, United States, Europe
Pseudococcus gahani Green Sap feeder on twigs and nuts *J. regia.* Author	California (Ventura Co.)
Pseudococcus maritimus (Ehrhorn) Sap feeder *J. regia.* Essig 26–283	California
Pulvinaria betulae (Linn.) Sap feeder *J.* sp. Green 18–239	
Pulvinaria vitis (Linn.) Sap feeder *J. nigra.* Hollinger 23–59	Europe, Mississippi, New York, United States
Robinia sp. Sap feeder *J.* sp. Brain 19–	South Africa
Saissetia oleae (Bernard) Sap feeder on twigs *J. regia.* Essig 26–299	Subtropical and tropical regions of world (Ventura Co.)
Toumeyella liriodendri (Gmel.) Sap feeder *J.* sp. Merrill and Chaffin 23–273	East of Mississippi, Europe

ALEYRODIDAE

Traileurodes waldeni (Britton) Sap feeder *J. cinerea, J. nigra.* Britton, W. E. correspondent	Connecticut

HEMIPTERA

TINGIDAE

Corythucha arcuata (Say) Sap feeder on leaves *J. cinerea.* Felt 06–720	Alabama, Colorado, Illinois, Quebec, Texas
Corythucha contracta Osborn and Drake Sap feeder *J. cinerea, J.* sp. Britton 23–701	Connecticut
Corythucha juglandis (Fitch) Sap feeder *J. cinerea* Weiss and Dickerson 18– *J.* sp. Leonard 28–101	British Columbia, California, Connecticut, Idaho, Illinois, Maine, New Jersey, New York, Oregon
Corythucha parshleyi Gibson Sap feeder *J. nigra, J. cinera, J. sibbaldiana* Weiss and Dickerson 18–	New Jersey
Stephanitis (*Tingis*) *pyri* Fabr. Sap feeder on leaves *J.* sp. Gantier, Bonnamour, and Chifflot 22–	Europe, Turkestan

MIRIDAE

Plagiognathus albatus (Van D.) Feeding at wound in fruit made by *Conotrachelus juglandis* Lec. *J. cinerea.* Brooks, F. E., correspondent	California, District Columbia, New York, Pennsylvania, West Virginia

COLEOPTERA

ORTHOPERIDAE

Sericoderus quadratus Csy. Adults taken commonly on decaying husks *J. regia.* Author	California (Ventura Co.)

ELATERIDAE

Ludius pyrrhos (Hbst.) Feeding in wound made in fruit by *Conotrachelus juglandis* Lec. *J. cinerea.* Brooks, F. E., correspondent	Alabama, Connecticut, Indiana, West Virginia

BUPRESTIDAE

Agrilus obsoletoguttatus Cory Adults frequently taken on foliage, larvae; as yet not found feeding on walnut. *J. cinerea, J. nigra.* Brooks, F. E., correspondent	Maine–Illinois, Indiana, West Virginia

Agrilus otiosus Say Borer in dead and dying twigs. *J. cinerea, J. nigra.* Blackman and Stage 24–66	Eastern Canada, New England–Kansas–Texas
Agrilus juglandis Knull Borer *J. cinerea* Knull 2–7	Pennsylvania
Anthaxia aeneogaster Cast. Borer in small branches *J. californica.* Essig 26–399	California, Canada, Arizona, Indiana
Chrysobothris femorata (Oliv.) Borer *J. cinerea, J. nigra.* Brooks, F. E. 19–5	United States
Chrysobothris mali Horn. Borer *J. regia.* Burke, H. E., correspondent	Southern California, Colorado, Arizona
Chrysobothris sexsignata (Say) Borer *J. nigra, J. cinerea.* Burke, H. E., correspondent	Arizona, Colorado, Eastern United States
Dicerca horni Cr. Borer in trunk and large branches of weakened trees *J. regia.* Essig 26–397	California (Ventura Co.)

DERMESTIDAE

The larvae of an undetermined dermestid (*Anthrenus ?*) feed commonly on shelled meats of *J. regia.* One larvae, 4 mm. long, has been kept under observation in the laboratory at Saticoy for two years and although it feeds and moults normally it has not become an imago.—Author.

OSTOMIDAE

Tenebroides mauritanicus (Linn.) Larvae feed on shelled walnuts *J. regia.* Essig 26–408	Cosmopolitan (Ventura Co.)

NITIDULIDAE

Carpophilus dimidiatus (Fab.) Larvae feeding on shelled nuts *J. regia.* Flanders, S. E.	Cosmopolitan (Ventura Co.)
Colopterus truncatus (Rand.) Sap feeder at freshly cut stumps *J. cinerea.* Felt 06–491	Canada, Florida, Indiana, California, Texas, New York
Cryptarcha concinna Melsh. Occurs at Sap *J. cinerea.* Felt. 06–491	Indiana, Middle States, Kansas, Texas, Southern California

CUCUJIDAE

Brontes dubius Fab. Beneath bark of dead trees *J. cinerea.* Felt 06–490	Iowa–New Jersey, Indiana, Louisiana, New York
Oryzaephilus surinamensis (Linn.) Feeding on stored nuts *J. regia.* Author	Cosmopolitan (Ventura Co.)

LATHRIDIIDAE

Enicmus crenatus Lec. — California (Ventura Co.), Texas, Utah
Feeding on rotting husks
J. regia. Author

ANOBIIDAE

Anobium rufipes Fabr. — Europe
Borer
J. sp. Kemner 16–

Coelostethus quadrulus (Lec.) — British Columbia–California (Ventura Co.), Nevada
Bred from dead wood
J. regia. Author

Hedobia granosa Lec. — California (Ventura Co.)
Borer in dead twigs
J. californica. Essig 26–433
J. regia. Author

Oligomerus brunneus Oliv.
Borer in dead wood
J. sp. Bofill and Pichot 16–

Vrilletta blaisdelli Fall — Southern California (Ventura Co.)
Bred from small branches and twigs
J. regia. Author

BOSTRICHIDAE

Polycaon confertus Lec. — California (Ventura Co.)
Borer in dead branches and twigs
J. regia. Flanders, S. E.

Polycaon stouti (Lec.) — California (Ventura Co.), Oregon, Lower California
Borer in weakened branches
J. regia. Flanders, S. E.

Xylobiops basillare (Say) — East of Rockies
Borer
J. sp. Blackman and Stage 24–82

LYCTIDAE

Lyctus brunneus (Steph.) — Cosmopolitan
Borer in seasoned wood
J. sp. Fisher 28–

Lyctus linearis (Goeze) — Cosmopolitan
Mines cured wood
J. sp. Essig 26–439

Lyctus parallelopipedus (Melsh.) — England, eastern and southeastern United States
Borer in seasoned wood
J. sp. Fisher 28–

Lyctus planicollis Lec. — England, United States (Ventura Co.)
Borer in dry wood
J. regia. Author
J. sp. Fisher 28–

SCARABAEIDAE

Copris minutus (Drury) Adults feeding in husks following attack of *Rhagoletis suavis* Loew *J. nigra.* Brooks, F. E., correspondent	Canada–Florida, Indiana, Texas
Cotinis nitida (Linn.) In bark? *J. nigra.* Felt 06–719	Connecticut–Virginia, Florida, Indiana, Louisiana
Dichromina dimidiata (Burm.) Leaf feeder *J.* sp. Essig 26–446	Arizona, southern California
Diplotaxis popino Csy. Leaf feeder *J.* sp. Essig 26–441	Arizona, New Mexico
Euphoria fulgida (Fab.) Adults feeding at wounds in young fruit made by *Conotrachelus juglandis* Lec. *J. cinerea.* Brooks, F. E., correspondent	Connecticut–Michigan–Indiana, West Virginia
Euphoria inda (Linn.) Adults feeding at wound in bark *J. nigra.* Brooks, F. E., correspondent	Arizona, Connecticut, Florida, Indiana, Nebraska, West Virginia
Macrodactylus subspinosus (Fab.) Feed on foliage and young nuts *J. cinerea, J. nigra.* Brooks, F. E., correspondent	Atlantic States, Colorado, Indiana, Virginia, West Virginia
Melolontha vulgaris Linn. Adults feed on foliage, larvae on roots *J. regia.* Sajo, Chas., correspondent	Europe
Pachystethus marginata (Fab.) Leaf feeder *J. nigra.* Brooks, F. E., correspondent	Florida, Indiana, Missouri, New Mexico, West Virginia
Phyllophaga forbesi Glasgow Leaf feeder *J.* sp. Forbes 16–226	Southern Illinois
Phyllophaga fraterna Harris Leaf feeder *J. nigra.* Forbes 16–228	Indiana, Maine–Iowa, North Carolina, Florida
Phyllophaga fusca (Froelich) Leaf feeder *J.* sp. Forbes 16–223	Indiana, Hudson Bay territory, Georgia–California, Newfoundland
Phyllophaga hirticula (Knoch) Leaf feeder *J. nigra.* Forbes 16–219	Indiana, Atlantic States, Texas
Phyllophaga ilicis (Knoch) Leaf feeder *J. nigra.* Forbes 16–230	Indiana, New York, Georgia, Illinois, Connecticut

Phyllophaga pearliae Davis — Tennessee, Indiana, Kentucky
Leaf feeder
J. sp. Davis 20–332

Phytalus pallidus Horn — Arizona
Leaf feeder
J. sp. Essig 26–442

Plusiotina lecontei (Horn) — Arizona, New Mexico
Leaf feeder
J. sp. Essig 26–445

Serica alternata Lec. — Southern California (Ventura Co.)
Leaf feeder
J. regia. Author

Thyce fossiger Csy. — Southern California
Leaf feeder
J. regia. Author

Thyce pistoria Csy. — Southern California (Ventura Co.)
Leaf feeder
J. regia. Author

LUCANIDAE

Dorcus parallelipipedus (Linn.) — Europe
"Obtained from broken and decaying stems of walnuts"
J. sp. MacDougall 16–

CERMANBYCIDAE

Arhopalus fulminans (Fab.) — Connecticut–Indiana
Borer
J. cinerea. Blatchley 10–1035

Astylopsis macula (Say) — Canada, Indiana, New York, Virginia, Wisconsin
Twig borer
J. cinerea, J. nigra. Blatchley 10–1072
J. regia. Felt 06–482

Brachyleptura vagans (Oliv.) — Canada–Georgia, Northeast States
Borer
J. cinerea. Felt 06–440

Centrodera decolorata (Harris) — Canada, Indiana, Massachusetts, Michigan, New Jersey, New York, Pennsylvania
Borer
J. cinerea. Felt 06–456

Cerambyx cerdo Linn. — Europe
Borer
J. sp. Pierce 17–220

Cerambyx heros Scop. — Cyprus
Borer in trunk around pruning wounds
J. sp. Anonymous 22–28

Cyllene robiniae (Forst.) — Canada, Connecticut, Indiana, United States
Borer
J. cinerea, J. nigra. Felt 05–264

Crytophorus verrucosus (Oliv.) — Canada, Eastern States west to Indiana and Michigan
Borer
J. sp. Blackman and Stage 24–107

Derobrachus brunneus (Forst.)	Connecticut, Indiana, northeast America
Borer in decaying wood	
J. sp. Felt 06–487	
Eupogonius vestitus (Say)	Canada–Alabama, Florida, Indiana, Texas
Borer	
J. sp. Felt 06–715	
Gaurotes cyanipennis (Say)	Canada–eastern North America, Indiana
Borer	
J. **alba.* Felt 06–454	
J. cinerea. Champlain, Kirk, Knull 25–107	
Goes tigrinus (De.G.)	Canada–Florida, Indiana, New York
Borer in solid wood	
J. sp. Felt 05–268	
Hetoemis cinerea (Oliv.)	Alabama, Connecticut, Illinois, Indiana, Louisiana, New Jersey, New York, Ohio
Borer in small limbs	
J. sp. Blackman and Stage 24–113	
Hypermallus villosus (Fab.)	Atlantic states–Texas, Connecticut, Indiana
Bores in twigs	
J. nigra, J. regia. Blackman and Stage 24–90	
Hyperplatys aspersa (Say)	Canada–Wisconsin–Florida, Connecticut, Indiana, New York
Borer	
J. cinerea. Blackman and Stage 24–119	
Hyperplatys californica Csy.	California (Ventura Co.)
Bred from stumps, branches and twigs of dead trees	
J. regia. Flanders, S. E.	
Ipochus fasciatus Lec.	Southern California (Ventura Co.)
Borer in small twigs	
J. regia. Author	
Liopus nebulosus Linn.	Europe (Austria)
Larvae bore in trunk	
J. regia. Sajo, Chas., correspondent	
Lepturges querci Fitch	Canada, Indiana, Michigan, New York, Ohio, Pennsylvania, Wisconsin
Borer in small branches	
J. cinerea. Blackman and Stage 24–118	
Mesosa curculionides Linn.	Europe (Germany)
Larvae bore in trunk	
J. regia. Sajo, Chas., correspondent	
Molorchus bimaculatus Say	Atlantic States, Indiana, Connecticut
Borer in small branches	
J. sp. Blackman and Stage 24–97	
Neoclytus acuminatus (Fab.)	Canada, Florida, Indiana, Nebraska, United States
Borer	
J. nigra. Webb 10–354	
Oberea linearis Linn.	Europe
Bores in pith of nursery stock	
J. sp. Pierce 17–220	

* Not listed as one of the recognized species of *Juglans*.

Oncideres cingulatus (Say) Adults sever small branches, larvae bore in severed branches *J.* sp. Gill 17–43	Eastern States, Central States, and Southern States
Ophistomis delicata (Lec.) Borer in dead branches *J. regia.* Author	California (Ventura Co.), Nevada
Parandra brunnea (Fab.) Borer *J. nigra.* Brooks 15–2	Connecticut, Indiana
Phymatodes juglandis Leng Borer in sapwood *J. californica.* Essig 26–456	Southern California
Prionus californicus Mots. Borer in dead roots *J. regia.* Essig 26–449 *J. californica.* Flanders, S. E.	California (Ventura Co.), Oregon
Pseudibidion unicolor (Rand.) Prunes small branches *J. nigra.* Champlain, Kirk, Knull 25–106	Canada–Florida, Indiana, northern states
Romaleum atomarium (Drury) Under bark of stumps *J.* sp. Felt 06–434	Connecticut, Florida, Indiana, Middle and Southern States
Saperda discoidea Fab. Borer *J. cinerea, J. regia.* Blackman and Stage 24–121	Connecticut, Indiana, Michigan–Louisiana, New York
Saperda scalaris (Linn.) Borer in trunk *J. regia.* Sajo, C., correspondent	Europe
Synaphoeta guexi (Lec.) Larvae bore in heartwood of dead and injured trees. *J. californica, J. regia.* Essig 15–253	Southern California, Vancouver
Tessaropa tenuipes (Hald.) Borer *J.* sp. Felt 06–715	New Jersey, New York, Pennsylvania
Tylonotus bimaculatus Hald. Borer *J. nigra.* Felt 06–726	India, North America, New York, Pennsylvania
Xylotrechus colonus (Fab.) Borer *J.* sp. Blackman and Stage 24–100	Canada–Georgia, Florida, Indiana
Xylotrechus nauticus (Mann.) Borer in large limbs and trunks of dying and dead trees *J. regia.* Essig 26–457	Montana–Southern California (Ventura Co.)

CHRYSOMELIDAE

Bassareus mammifer (Newn.) Leaf feeder *J. regia.* Felt 06–719	Connecticut, Indiana, middle and western states
Chaetocnema confinis Cr. At times abundant on foliage; feeding not observed *J. regia.* Author	California (Ventura Co.), Connecticut–Florida, Indiana
Diabrotica soror Lec. Leaf feeder *J. regia.* Flanders, S. E.	Arizona, California (Ventura Co.) Oregon
Gastrolina thoracica Baly Leaf feeder *J. sieboldiana,* Yuasa 27–	Japan
Leperodes thoracicus Melsh. Leaf feeder *J. cinerea.* Guyton 27–	Pennsylvania
Metachroma luridum (Oliv.) Leaf feeder *J. sieboldiana.* Harvey 95–430	Georgia, South Carolina
Paria canella (Fab.) Leaf feeder *J. cinerea.* Felt 06–537	Canada, Arizona, Indiana, Southern California

CURCULIONIDAE

Aloides porrectirostris Marshall Breeds in nuts *J. regia.* Pierce 17–220	India
Anthonomus profundus Lec. Leaf feeder *J. regia.* Felt 06–719	Illinois, Maryland, New York, Pennsylvania, Quebec
Attelabus analis Ill. Leaf-roller *J. nigra.* Felt 06–720	Canada, Florida, Texas
Attelabus bipustulatus Fab. Beaten from leaves *J.* sp. Blatchley and Leng 16–63	Ontario–Massachusetts–Wisconsin, south to Mississippi, Florida, and Texas
Calandra oryzae (Linn.) C. P. Lounsbury writes, "I have the impression *Calandra oryzae* has been reared from walnuts as it has from acorns but written record is lacking." *J. regia.* Lounsbury, C. P., correspondent	Alaska, Europe, South Africa, United States
Conotrachelus anaglypticus (Say) Oviposit in fruit? *J.* sp. Felt 06–544	Florida, Iowa, New England, Pennsylvania
Conotrachelus juglandis Lec. Larvae tunnel in green shoots and fruit: adults feed at base of leaves	Quebec–Georgia–Illinois

J. cinerea, J. cordiformis, J. mandshurica, J. nigra, J. regia, J. sieboldiana Britton and Kirk 12–247	
Conotrachelus retinus (Say) Feed on fruit *J. cinerea, J. nigra.* Brooks 22–	Florida, Kansas, Pennsylvania
Cossonus impressifrons Boh. Under dead bark *J. cinerea.* Blackman and Stage 24–133	Canada–Georgia–Arizona, Florida
Cossonus platalea Say Under dead bark: bred from *J. cinerea* wood. *J. cinerea.* Felt 06–455 *J. nigra.* Blatchley and Leng 16–530	Canada–Virginia–Iowa
Cryptorhynchus parochus (Hbst.) Larvae mine inner bark and sapwood of weakened and dead trees *J. cinerea.* Felt 06–494	Canada, Florida, Iowa
Eugnamptus angustatus Hbst. Leaf feeder *J. cinerea.* Felt 06–720	Canada–Texas
Eugnamptus collaris (Fab.) Leaf feeder *J. cinerea.* Felt 06–716 *J. cinerea, J.* sp. Blatchley and Leng 16–56	Florida, Kansas, Massachusetts
Magdalis carbonaria Linn. Borer in trunk *J.* sp. Pierce 17–220	Europe
Magdalis inconspicua Horn Borer *J. nigra.* Felt 06–719	Canada, Pennsylvania, Texas, West Virginia
Magdalis pandura Say Bred from dead and dying trees *J. nigra.* Blatchley and Leng 16–260	Ontario–Massachusetts–Wisconsin south to Missouri and Georgia
Magdalis salicis Horn Borer *J. cinerea.* Felt 06–720	Indiana, Massachusetts, Maine
Pantomorus godmani (Crotch) Leaf feeder *J. regia.* Author	California (Ventura Co.), Massachusetts, Montana, New Jersey, Europe, Hawaiian Islands
Peritelus griseus Oliv. Injuring shoots and young branches *J. regia.* Gomilevsky 15–	Germany, Hungary
Phloeophagus californicus Van D. Larvae and adults bore in dead limbs *J. regia.* Author	Southern California (Ventura Co.)
Rhyncolus angularis Lec. Larvae and adults bore in dead limbs *J. regia.* Author	Southern California (Ventura Co.)

Stenomimus pallidus Boh.	Illinois, Indiana, Ohio, Pennsylvania
Larvae and adults under bark	
J. nigra. Blatchley and Leng 16–535	
Stenoscelis brevis (Boh.)	Canada, Florida, Kansas
Bore in dead wood	
J. cinerea. Felt 06–494	

SCOLYTIDAE

Chramesus hicoriae Lec.	Eastern Canada, eastern United States
Bred from twigs	
J. sp. Blackman and Stage 24–143	
Cryphalus scopiger Berger	Ussuria
Borer in dying branches	
J. mandshurica. Berger 17–	
Dryocoetes granicollis Lec.	District of Columbia, New Jersey, Pennsylvania, West Virginia
Borer	
J. cinerea. Blatchley and Leng 16–611	
Hypothenemus juglandis Blackm.	Mississippi
Borer in inner bark and wood of dead and decaying sprouts from stump	
J. nigra. Blackman 22–88	
Micracis hirtellus Lec.	California (Ventura Co.)
Borer	
J. regia. Author	
Micracis suturalis Lec.	Louisiana, Kansas, Massachusetts, Michigan, New York, Virginia
Borer	
J. nigra. Felt 06–715	
Scolytus geoffrayi Goeze	
Insect not seen, identified only by work in dead tree	
J. sp. Schulze ?–59	
Scolytus quadrispinosus Say	Southeastern Canada, Vermont–Utah, Georgia
Borer in larval and adult stages	
J. cinerea, J. nigra. Blackman and Stage 24–135	
Stephanoderes sp. (near *georgiae*)	Mississippi
Associated with *Hypothenemus juglandis* Blackm.	
J. nigra. Blackman 22–95	
Xyleborus fuscatus Eich.	District of Columbia, Florida, Indiana, Mississippi, North Carolina, New Jersey, Texas
Borer	
J. cinerea. Blatchley and Leng 16–622	
J. sp. Blackman 22–622	
Xyleborus planicollis Zimm.	District of Columbia, Maryland, Pennsylvania, Colombia, Guatemala
Borer in wine and vinegar casks made of walnut wood	
J. sp. Blatchley and Leng 16–618	
Xyleborus pubescens Zimm.	Alabama, Florida, Virginia
Borer	
J. cinerea. Felt 06–702	

DIPTERA

MYCETOPHILIDAE

Leia bivittata Say — New York, West Virginia
Reared from nut injured by *Conotrachelus retinus* (Say)
J. nigra. Brooks, F. E., correspondent

SCATOPSIDAE

Rhegmoclema atrata Say — California (Ventura Co.), New York, West Virginia
Reared in abundance from nuts of *J. nigra* injured by *Conotrachelus retinus* (Say). Commonly reared from blighted husks of *J. regia*
J. nigra. Brooks, F. E., correspondent
J. regia. Author

MUSCIDAE

Muscina stabulans (Fallen) — United States (Ventura Co., California)
Reared from decaying walnut husks.
J. regia. Author

Stomoxys calcitrans (Linn.) — Europe, United States (Ventura Co., California)
Reared from decaying nuts
J. regia. Author

ANTHROMYIIDAE

Fannia canicularis (Linn.) — Cosmopolitan
Reared from decaying husks
J. regia. Author

Helina procedens Walk. — California (Ventura Co.), New York
Larvae found in bleeding wounds
J. regia. Flanders, S. E.

LONCHAEIDAE

Lonchaea occidentalis Mall. — California (Ventura Co.)
Bred from the husks of blighted nuts
J. regia. Author

Lonchaea polita Say — California (Ventura Co.)
Under moist dead bark on limbs scorched by fire also under bark killed by Melaxuma
J. regia. Flanders, S. E.

ORTALIDAE

Euxesta putricola Cole — Western states
Bred from husks of blighted nuts
J. regia. Author

Euxesta n. sp. Cole — California (Ventura Co.)
Bred from husks of blighted nuts
J. regia. Author.

TRYPETIDAE

Dacus (*Chaetodacus*) *tryoni* var. *juglandis* Froggatt From walnut *J.* sp. Tryon 27–	Queensland
Rhagoletis boycei Cress. Larvae feed on green husks *J. regia.* Boyce 30–253	Arizona
Rhagoletis juglandis Cress. Larvae feed on green husks and kernels *J. regia, J. rupestris.* Brooks 21–1	Arizona, Texas
Rhagoletis suavis Loew Larvae feed on green husks *J. cinerea, J. nigra, J. regia, J. sieboldiana.* Brooks 21–3	Middle states, North Atlantic states
Rhagoletis suavis sub-species *completa* Cress. Larvae feed on green husks *J. californica, J. hindsii, J. regia.* Boyce 30–250	Southern California, Texas

CHLOROPIDAE

Madiza nucis Perris Larvae in nuts injured by codling moth *J. regia.* Howard 87–93	Europe

DROSOPHILIDAE

Drosophila amoena Loew Reared from green nut *J. nigra.* Brooks, F. E., correspondent	West Virginia
Drosophila buscki Coq. Larvae feeding in husks injured by *Rhagoletis suavis* *J. regia.* Brooks, F. E., correspondent	New York, Pennsylvania
Drosophila hydei Sturt. Bred from husks of blighted nuts *J. regia.* Author	California (Ventura Co.), New York
Drosophila melanogaster Meig. Bred from husks of blighted nuts *J. regia.* Author	Cosmopolitan
Drosophila quinaria Loew Bred from decaying nuts *J. nigra, J. regia.* Brooks, F. E., correspondent	New York, Pennsylvania, West Virginia

LEPIDOPTERA

LYCAENIDAE

Theola calanus Hbn.	Atlantic states, Quebec–Colorado, Texas
Leaf feeder	
J. cinerea, J. nigra. Felt 06–704	

SPHINGIDAE

Cressonia juglandis Abb. & Sm.	Atlantic States, Mississippi Valley
Leaf feeder	
J. cinerea. Lutz 21–495	
J. nigra. Felt 06–720	
Oxyambulyx sericeipennis Butl.	India
Leaf feeder	
J. sp. Fletcher 19–	

CERATOCAMPIDAE

Basilona imperialis Drury	Atlantic States
Leaf feeder	
J. cinerea. Comstock 20–717	
Citheronia regalis Fabr.	New York, Virginia
Leaf feeder	
J. cinerea, J. nigra. Felt 05–305	

SATURNIIDAE

Dictyoploca japonica Butl.	Japan
Leaf feeder	
J. sieboldiana. Yuasa, Hacluro, correspondent	
Saturnia pyri Schiff.	Europe
Leaf feeder	
J regia. Sajo, Chas., correspondent	
Telea polyphemus (Cramer)	United States
Leaf feeder	
J. cinerea. Comstock 20–722	
J. nigra. Felt 06–526	
Tropoea luna Linn.	Atlantic States, Mississippi Valley
Leaf feeder	
J. sp. Felt 06–526	

ARCTIIDAE

Arctia caia Linn.	Northern palaearctic region
Leaf feeder	
J. regia. Sajo, Chas., correspondent	
Diacrisia virginica (Fabr.)	United States
Leaf feeder	
J. cinerea. Felt 06–720	
Halisidota caryae (Harris)	Atlantic states–Minnesota–Missouri–Saskatchewan, North Carolina
Leaf feeder	
J. cinerea. Felt 05–314	
J. nigra, J. regia, J. sieboldiana. Isely 18–5	

Hyphantria cunea (Drury) Leaf feeder *J. Californica.* Essig, E. O., correspondent *J. regia.* Essig 26–677	Southern Atlantic States, Arizona, British Columbia, California, Colorado, Idaho, Washington

NOCTUIDAE

Allotria elonympha Hbn. Leaf feeder *J. Nigra.* Felt 06–720	Atlantic States, New York
Apatela impleta Walk. Leaf feeder *J. nigra.* Felt 06–749	New York
Bomolocha madefactalis Guen. Leaf feeder *J. nigra.* Felt 06–720	Atlantic States, Florida, New York
Catocala californica Edw. Leaf feeder *J. regia.* Author	California (Ventura Co.)
Catocala habilis Grote Leaf feeder *J. nigra.* Felt 06–716	Atlantic States, New York
Catocala innubens Guen. Leaf feeder *J. nigra.* Felt 06–729	Atlantic States
Catocala lacrymosa Guen. Leaf feeder *J. regia.* Felt 06–705	Atlantic States
Catocala neogama Sm. & Abb. Leaf feeder *J. regia.* Felt 06–719	Atlantic States
Catocala palaeogama Guen. Leaf feeder *J. nigra.* Felt 06–716	Atlantic States
Catocala piatrix Grote Leaf feeder *J. regia.* Felt 06–719	Atlantic States
Catocala subnata Grote Leaf feeder *J. nigra.* Felt 06–720	Atlantic States
Catocala vidua Abb. & Sm. Leaf feeder *J. nigra.* Felt 06–705	Atlantic States
Colocasia propinquilinea Grote Leaf feeder *J. regia.* Felt 06–749	Atlantic States
Monodes versiocolor Grote Leaf feeder *J. nigra.* Felt 06–754	Atlantic States
Pyrophila pyramidoides Guen. Leaf feeder *J. regia.* Sajo, Chas., correspondent	Atlantic States, Colorado, Europe

NOTODONTIDAE

Datana integerrima Gr. & Rb. Leaf feeder *J. cinerea, J. nigra, J. regia.* Felt 05–303–5	Atlantic States, California, Kansas, Kentucky
Datana ministra (Drury) Leaf feeder *J.* sp. Essig 26–691	British Columbia, United States (Ventura Co.)
Hemerocampa leucostigma (Abb. & Sm.) Leaf feeder *J. cinerea, J. nigra.* Felt 05–132	Eastern States–Colorado, British Columbia
Hemerocampa vetusta (Bdv.) Leaf feeder *J. californica.* Author *J. regia.* Essig 26–692	British Columbia, Pacific States (Ventura Co.)
Heterocampa guttivitta Walk. Leaf feeder *J.* sp. Hitchings 10–146	Massachusetts, Maine, New York, New Hampshire, Rhode Island, Illinois
Heterocampa manteo Dbldy. Leaf feeder *J. regia.* Felt 06–705	Atlantic States
Heterocampa umbrata Walk. Leaf feeder *J. nigra.* Felt 06–705	Atlantic States
Schizura concinna (Abb. & Sm.) Leaf feeder *J. cinerea.* Houser, J. S., correspondent *J. regia.* Essig 26–691	United States
Schizura leptinoides Grote Leaf feeder *J. nigra.* Felt 06–716	Atlantic States
Stauropus fagi Linn. Leaf feeder *J. regia.* Sajo, Chas., correspondent	Europe

LASIOCAMPIDAE

Malacosoma disstria Hbn. Leaf feeder *J. nigra, J. regia.* Felt 05–106–15	United States

GEOMETRIDAE

Alsophila pometaria (Harris) Leaf feeder *J. cinerea, J. nigra.* Porter and Alden 24–5–6	California, Colorado, New Mexico, Northeastern states, eastern Canada
Coniodes plumogeraria (Hulst) Leaf feeder *J. regia.* Essig 26–700	British Columbia, California (Ventura Co.), Colorado, Oregon, Washington

Ennomos subsignarius Hubn. — Atlantic States, California (Ventura Co.)
Leaf feeder
J. regia. Flanders, S. E.

Nemoria bistriaria Hbn. — Atlantic States
Leaf feeder
J. nigra. Felt 06–720

Paleacrita vernata (Peck) — Northeastern America, California, New Mexico, Utah
Leaf feeder
J. nigra. Porter and Alden 24–5

Sabulodes carberata Guenée — California
Leaf feeder
J. sp. Essig 26–701

Sabulodes forficularia Guenée — California (Ventura Co.)
Leaf feeder
J. regia. Essig 26–703

PYRALIDAE

Acrobasis caryae Grote — Illinois, Massachusetts, Maryland, New York, Texas
Larvae feed on buds, leaves and stems; also bore in stems
J. cinerea, *J. nigra*, *J. regia.* Kirk 12–254

Acrobasis demotella Grote — Ontario–New York
Twig borer
J. nigra. Felt 06–719

Acrobasis nebulella Riley — Atlantic States, District of Columbia, Florida, Missouri, Texas, France
Bores in buds, feeds on leaves
J. sieboldiana, *J.* sp. Gill 17–4

Aphomia gularis Zell. — China, England, India, United States
Bred from walnuts in storage
J. sp. Laing 22–191

Ephestia elutella (Hbn.) — Asia, Europe, Pacific islands, North America
Larvae feed on stored nuts
J. regia. Essig 26–711

Ephestia kuehniella Zeller — Cosmopolitan (Ventura Co.)
Larvae feed on shelled walnuts
J. regia. Author

Euzophera aeglacella Ragonot — Arizona, Mexico, Utah
Mines cambium
''Native black walnut of region'' *J. rupestris?* Essig 26–710

Mineola juglandis LeB. — Atlantic states
Leaf feeder
J. regia. Felt 06–719

Myelois ceratoniae Zell. — South Africa
Reared from stored nuts
J. regia. Lounsbury, E. P., correspondent

Plodia interpunctella (Hbn.) — Cosmopolitan (Ventura Co.)
Larvae feed on stored nuts
J. regia. Author

EUCOSMIDAE or OLETHREUTIDAE

Argyroploce leucotreta Meyr. — Eastern Cape Colony, Natal, Rhodesia, Transvaal
Larvae tunnel in green fruit
J. regia. Lounsbury, C. P., correspondent

Carpocapsa pomonella (Linn.) — Cosmopolitan (Ventura Co.)
Larvae tunnel green fruit
J. regia. Quayle 26–1

Carpocapsa pomonella var. *simpsoni* Busck — California (Ventura Co.)
Larvae tunnel green fruit
J. regia. Author

Carpocapsa splendana Hbn. — Italy
Feeds on fruit
J. sp. Chiari 20–631

Gretchena biangulana Wals. — California (Ventura Co.)
Larvae feed on green fruit
J. californica Flanders, S. E.

Laspeyresia amplana Hbn. — Europe
Borer in fruit?
J. sp. Pierce 17–220

Laspeyresia caryana Fitch — Atlantic states, Illinois
Larvae tunnel shucks
J. sp. Felt 06–583

Laspeyresia grossana Haworth — Europe
Borer in fruit?
J. sp. Pierce 17–220

Laspeyresia splendana Hbn. — Europe
Borer in fruit?
J. sp. Pierce 17–220

Melissopus latiferreanus (Walsingham) — Maine–California (Ventura Co.)
Larvae feed on green husks, larvae hibernate under codling moth bands
J. regia. Author

TORTRICIDAE

Archips argyrospila Walker — United States (Ventura Co.)
Larvae feed on leaves and husks of green nuts
J. nigra. Gill 13–93
J. regia. Essig 26–735

Eulia juglandana Fern. — Massachusetts–Minnesota
Leaf feeder
J. regia. Felt 06–717

Proteopteryx bolliana Sling. — Southern states
Feeds on buds
J. nigra. (Doubtful record.) Gill 17–25

Sparganothis sp. — California (Ventura Co.)
Feed on husks of green nuts
J. regia. Flanders, S. E.

Tortrix amplana Hbn. — Southern Europe, Northern Africa
Leaf feeder
J. regia. Sajo, Chas., correspondent

Tortrix citrana Fernald — California (Ventura Co.), Brazil
Leaf feeder
J. californica, J. regia. Author

HELIOZELIDAE

Coptodisca juglandiella Chamb. — Kentucky, New York
Leaf miner
J. nigra. Felt 06–720

COLEOPHORIDAE

Coleophora caryaefoliella Clem. — Florida–Texas–New Hampshire
Feeds on leaves and buds
J. nigra. Gill 17–23

GRACILARIIDAE

Cameraria caryaefoliella Clem. — Atlantic states
Leaf miner
J. cinerea, J. nigra. Felt 06–717

Gracilaria juglandiella Chamb. — Kentucky, New York, Pennsylvania
Mines under surface of leaf
J. nigra. Felt 06–720

Gracilaria roscipennella Hbn. — Switzerland
Leaf miner
J. Regia, Hering 26–

COSSIDAE

Cossus cossus Linn. — Europe
Bores in branches
J. regia. Sajo, Chas., correspondent

Zeuzera pyrina Linn. — Africa, Algeria, Asia Minor, Europe, Japan, Morocco, Sweden, Atlantic states
Borer in live wood
J. sp. Howard and Chittenden 16–5

NEPTICULIDAE

Nepticula juglandifoliella Clem. — California (Ventura Co.), New York, Pennsylvania
Leaf miner
J. californica, J. hindsii, J. regia. Author
J. nigra. Felt 06–720

HYMENOPTERA

XYELIDAE

Odontophytes avingrata (Dyer) Larvae feed on immature leaves *J. cinerea.* Leonard 28–871	New York

TENTHREDINIDAE

Eriocampa juglandis Fitch Leaf feeder *J. cinerea.* Felt 06–720	New York
Monophadnus caryae Nort. Feed on terminal part of leaf leaving midrib and small basal portion *J. cinerea.* Felt 24–295	New York

FORMICIDAE

Camponotus caryae subsp. *discolor* var. *clarithorax* Emery Borer in dead wood *J. regia.* Flanders, S. E.	California (Ventura Co.)
Camponotus truncatus Spin. Nest in twigs *J. regia.* Forel 01–380	Switzerland
Camponotus sp. In husk injured by *Conotrachelus juglandis* Lec. *J. cinerea.* Brooks, F. E., correspondent.	West Virginia
Dolichoderus quadripunctatus Linn. Nest in twigs *J. regia.* Forel 01–380	Switzerland
Iridomyrmex humilis Mayr Nests in cavities of trunk and large branches *J. regia.* Author	Argentina, Brazil, California (Ventura Co.), Louisiana
Lasius fuliginosus Latr. Nests in cavities of trunk where it makes a carton nest *J. regia.* Forel 01–381	Switzerland
Leptothorax affinis Mayr Nests in twigs *J. regia.* Forel 01–381	Switzerland
Solenopsis geminata (Fab.) Enter fallen nuts and feed on meats *J. regia.* Author	American tropics north to southern states, California (Ventura Co.)–British Columbia

XYLOCOPIDAE

Xylocopa varipuncta Patton Constructs nests in dead wood *J. regia.* Author	Arizona, California (Ventura Co.), Lower California

PHYLA NEMATHELMINTHES[1]

CLASS NEMATODIA

ORDER NEMATOIDEA

TYLENCHIDAE

Heterodera radicicola Greef. — California (Ventura Co.), South Africa
Forms galls on roots, feeds on sap.
J. regia. Flanders, S. E.

Heterodera schactii Schmidt — California (Ventura Co.)
Forms galls on roots, feeds on sap.
J. regia. Flanders, S. E.

LIST OF ORDERS AND NUMBERS OF FAMILIES, GENERA, AND SPECIES RECORDED

Class	Order	Families	Genera	Species and Varieties
Arachnida	Araneae	4	6	9
Insecta	Orthoptera	3	3	3
	Isoptera	2	3	4
	Thysanoptera	2	4	4
	Homoptera	7	37	67
	Hemiptera	2	3	6
	Coleoptera	17	99	130
	Diptera	9	12	21
	Lepidoptera	17	55	80
	Hymenoptera	4	10	12
Nematodia	Nematoidea	1	1	2
	Grand Total	68	233	338

[1] Although these two species do not belong to the same phyla as the insects and arachnids they are included here as they are of interest to the student.

BIBLIOGRAPHY

ANONYMOUS

1922. Carob tree destruction by the great capricorn beetle. Cypress Agr. Jour. **17**, pt. 2:28.

BANKS, N., and SNYDER, T. E.

1920. Revision of nearctic termites. U. S. Nat. Mus., Bulletin **108**:1–228.

BATCHELOR, L. D.

1929. Walnut culture in California. Univ. of Calif. College of Agriculture, Bulletin **379**:1–110.

BERGER, V. M.

1917. The Scolytids of the South-Ussurian Province. Revue Russe d'Entomologie, **16**:226–248.

BLACKMAN, M. W.

1922. Mississippi bark beetles. Miss. Agr. Exp. Station, Technical Bulletin **11**:1–130.

BLACKMAN, M. W., and STAGE, H. H.

1924. On the succession of insects living in the bark and wood of dying, dead and decaying hickory. Syracuse Univ. N. Y. State College of Forestry, Technical Publication **17**:3–269.

BLATCHLEY, W. S.

1910. The Coleoptera or beetles of Indiana. Ind. Dept. of Geology and Natural Resources, Bulletin **1**:1–1386.

BLATCHLEY, W. S., and LENG, C. W.

1916. Rhynchophora or weevils of North eastern America (Nature Publishing Co., Indianapolis), pp. 1–682.

BOFILL, and PICHOT, J. M.

1916. Anatomical and biological notes on *Oligomerus brunneus* Oliv. and its parasite *Pediculoides ventricosus* Newp. (Translated title.) Memorias R. Acad. Cienc. y Artes (Barcelona) **12**:201–218.

BOYCE, A. M.

1930. The walnut husk fly. Monthly Bulletin Dept. of Agr., State of California, pp. 249–253.

BRAIN, G. K.

1919. The Coccidae of South Africa, part 3, 3 (Bull. Entom. Research, London) **9**:197–239.

BRITTON, W. E.

1923. Guide to the insects of Connecticut. State of Conn., State Geological and Natural History Survey Bull. **34**:1–806.

BRITTON, W. E., and KIRK, H. B.

1912. The life history and habits of the walnut weevil or curculio. Conn. Exp. Station Report **1912**:240–253.

Brooks, F. E.
1915. The parandra borer as an orchard enemy. U. S. Dept. Agr. Bulletin **262**:1–7.
1919. The flat-headed apple tree borer. U. S. Dept. Agr. Farmer's Bulletin **1065**:3–12.
1921. Walnut husk-maggot. U. S. Dept. Agr. Bulletin **992**:1–11.
1922. Curculios (*Conotrachelus* spp.) that attack the young fruits of walnuts and hickory. U. S. Dept. Agr. Bulletin **1066**:1–16.

Champlain, A. B., Kirk, H. B., Knull, J. N.
1925. Notes on Cerambycidae. Entom. News, **36**:105–109.

Chiari, M.
1920. Due Vermi delle Castagne (Two larvae injurious to chestnuts). Riv. Agr., Parma, **26**:631.

Comstock, J. H.
1924. An introduction to entomology (Comstock Publishing Co., Ithaca, N. Y.), pp. xix:1–1040.

Davidson, W. M.
1914. Walnut aphids in California. U. S. Dept. Agr. Bulletin **100**:1–48.

Davis, J. J.
1920. New species and varieties of *Phyllophaga*. Bull. Illinois Nat. Hist. Survey, **13**:329–338.

Essig, E. O.
1915. Injurious and beneficial insects of California. Suppl. to Bulletin Calif. Comm. Hort., **4**:1–541.
1926. Insects of Western North America (Macmillan Co., N. Y.), pp. 1–1035.

Felt, E. P.
1905. Insects affecting park and woodland trees. New York State Mus. Memoir **8**:1–459.
1906. Insects affecting park and woodland trees. *Ibid.*, 333–877.
1924. Manual of tree and shrub insects (Macmillan Co., N. Y.), pp. 1–382.

Fisher, R. G.
1928. Timbers and their condition in relation to *Lyctus* attack. Forestry, **2**:40–46 (London).

Fletcher, T. B.
1919. Report of the imperial entomologist. Sci. Repts. Agr. Res. Inst., Pusa, **1918–19**: 86–103.

Forbes, S. A.
1916. A general survey of the may beetles (*Phyllophaga*) of Illinois. Univ. of Ill. Agr. Exp. Station Bulletin **186**:215–257.

Forel, A.
1901. (Title not known). Annals Entom. Soc. Belgium, **45**:380–382.

Funkhouser, W. D.
1917. Biology of the Membracidae of the Cayuga lake basin. Cornell Univ. Agr. Exp. Station, Memoir **11**:177–445.

Gantier, C., Bonnamour, S., and Chifflot, J.
1922. Observations biologiques sur *Tingis pyri* F., le Tigre de Poirier. Ann. Soc. Linn. Lyon, n.s., **69**:160–166.

GILL, J. B.

1913. The fruit-tree leaf-roller. U. S. Dept. Agr. Bulletin 116:91–110.

1917. Important pecan insects and their control. U. S. Dept. Agr. Farmer's Bulletin 843:1–48.

1917. The pecan leaf case-bearer. *Ibid.*, 571:1–28.

GIRARDI, J.

1922. En el Nogal. Nuevas Enfermedades de las Hojas y de las Frutas (In the walnut plantation: New injuries of the leaves and fruits.) Uruguay: Minist. Indust., Defensa Agricola., Bol. Mens., Montevideo, 2:111–112.

GOMILEVSKY, V.

1915. The walnut *Juglans regia* L. (translated title) Published by Rostov-on- Don Society of Horticulture), 26 pp.

GREEN, E. E.

1918. A list of Coccide affecting various genera of plants. Annals of Applied Biology, 4:228–239.

GUYTON, T. L.

1927. Notes on the occurrence of *Leperodes thoracicus* as an insect pest of fruit trees. Jour. Econ. Ent., 20:193–194.

HARVEY, S. S.

1895. Notes from correspondence. Insect Life, 7:430.

HASEMAN, L.

1915. The peridocal cicada in Missouri. Missouri Agr. Exp. Sta. Bull. 137:1–33.

HERING, M.

1926. Eine neve *Phytomyzoptera* (*Phytomyptera*) Art. (Dipt. Tachin.). Konowia, 5:21–24 (Vienna).

HITCHINGS, E. F.

1910. The unprecedented appearance of the saddled-prominent. Jour. Econ. Ent., 3:146–148.

HOLLINGER, A. H.

1923. Scale insects of Missouri. Univ. of Missouri, College of Agr., Agr. Exp. Sta. Res. Bulletin 58:3–71.

HOWARD, L. O.

1887. Report of the entomologist. Report of the Dept. of Agr. 1887:48–179.

1894. Damage by the American locust. Insect Life, 7:220–229.

HOWARD, L. O., and CHITTENDEN, F. H.

1916. The leopard moth: a dangerous imported insect enemy of shade trees. U. S. Dept. Agr. Farmer's Bulletin 708:1–10.

ISELY, D.

1918. Orchard injury by the hickory tiger-moth. U. S. Dept. Agr. Bulletin 598:1–14.

KEMNER, N. A.

1916. Some new or little known enemies of fruit trees, with a summary of the life-history of those which attack the trunk and the branches (translated title). Meddelande no. 133, Centralanstulten för Försöksväsendet på Jordbruksområdet, Stockholm, Entomol. Avdln, no. 25, 21 pp.

KIRK, H. B.
1912. The walnut bud-moth. Conn. Exp. Station Report, 1912:253–258.

KNULL, J. N.
1920. Notes on Buprestidae. Ent. News, 31:4–12.

LAING, F.
1922. An Eastern species of Galleridae imported into Britain. Ent. Mon. Mag., p. 191.

LEONARD, M. D. (Editor)
1928. A list of the insects of New York with a list of the spiders and certain other allied groups. Cornell Univ. Agr. Exp. Station Memoir 101:1–1121.

LINDINGER, LEONHARD
1912. Die Schildläuse (Coccidae) pp. 1–388.

LUTZ, F. E.
1921. Field book of insects (G. P. Putman's Sons, New York and London), pp. 1–562.

MACDOUGALL, R. S.
1916. *Sinodendron cylindricum*, L and related Lamellicorns. Trans. R. Scottish Arboricultural Soc., pp. 50–55.

McGILLIVRAY, A. D.
1921. The Coccidae (Scarab Co., Urbana, Ill.), pp. 1–502.

MERRILL, G. B., and CHAFFIN, J.
1923. Scale-insects of Florida. Quarterly Bulletin State Plant Board, Fla., pp. 177–298.

MOULTON, D.
1907. A contribution to our knowledge of the Thysanoptera of Calif. U. S. Dept. Agr., Tech. Series, 12:39–68.

PARROTT, P. J., and FULTON, B. B.
1913. Notes on tree crickets. Jour. Econ. Ent. 6:177–180.

PIERCE, W. D.
1917. A manual of dangerous insects likely to be introduced in the United States through importations. U. S. Dept. Agr. Contribution of the Bureau of Entomology in Collaboration with The Federal Horticultural Board, pp. 1–256.

PORTER, C. E.
1924. Neuvo huesped de un Tisanoptero (the new host of a Thysanopteron). Rev. Chilian Nat. Hist., 28:97.

PORTER, B. A., and ALDEN, C. H.
1924. The cankerworms. U. S. Dept. Agr. Bulletin 1238:1–37.

QUAYLE, H. J.
1917. Some comparisons of *Coccus citricola and C. hesperidum.* Jour. Econ. Entom. 10:373–376.
1926. The codling moth in walnuts. Univ. of Calif. Exp. Station Bulletin 402:1–33.

SCHULZE, P.
——. *Scolytus geoffroyi* Goeze, on the walnut (translated title). Insektenboil, 9:59.

SNYDER, T. E.
1916. Termites, or "white ants," in the United States: their damage, and methods of prevention. U. S. Dept. Agr. Bulletin 333:1–32.

SWAIN, A. F.
1919. A synopsis of the Aphididae of California. Univ. of Calif. Publ. Entom., 3:1–221.

TAKAHASHI, R.
1924. Some Aphididae from the far East. Philippine Jour. Sci., 24:711–717.

THEOBALD, F. V.
1924. Entomological Department Ann. Rept. Res. and Adv. Dept. (S. E. Agr. Coll.), 1923–24, app. B, pp. 5–16.

THOMPSON, B. G.
1929. Note on the occurrence of the dusky-veined walnut aphis, *Callipterus juglandis* Frisch (an European insect) in America. Jour. Econ. Entom., 22:270.

TRYON, H.
1927. Queensland fruit flies (trypetidae) Series 1. Proc. R. Soc. Queensland, 38:176–224.

WATSON, J. R.
1923. Synopsis and catalog of the Thysanoptera of North America. Fla. Agr. Exp. Station Tech. Bulletin 168:1–100.

WEBB, J. L.
1910. Injuries to forest and forest products by roundheaded borers. Yearbook of the Dept. of Agr., pp. 341–358.

WEISS, H. B., and DICKERSON, E. D.
1918. The life-history and early stages of *Corythucha parshleyi* Gibson. Canadian Entomologist 50:401–406.

WILSON, H. F., and VICKERY, R. A.
1918. A species list of the Aphididae of the world and their recorded food plants. Trans. Wis. Acad. Sci. Arts and Letters, 19:22–355.

YUASA, H.
1927. Notes on the Japanese Chrysomelidae 1. On the food plants of several species (1.) Kontyu, 2:130–133. Tokyo. (In Japanese.)

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STUDIES OF HABROCYTUS CEREALELLAE (ASHMEAD), A PTEROMALID PARASITE OF THE ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* (OLIVIER)

BY

NORMAN S. NOBLE

INTRODUCTION

The stocks of the parasite *Habrocytus cerealellae* (Ashm.), were forwarded to the writer by Professor H. S. Smith, from the Citrus Experiment Station at Riverside, California, at the close of August 1930. At the Riverside Experiment Station it was present as a parasite of *Sitotroga cerealella* (Olivier) in maize, which was being used by Stanley E. Flanders in connection with the mass production of *Trichogramma minutum* Riley.

Nothing apparently has been written concerning this parasite since its original description and it was therefore decided that a study of its biology and morphology would be of value. The work was begun at the University of California, Berkeley, at the beginning of September 1930 and was continued until the end of March 1931.

During this time a study of the parasite's biology was carried out, together with morphological studies of the larva and the adult, the latter studies being more or less confined to those parts which have some connection with the biology.

ACKNOWLEDGMENTS

The writer wishes to acknowledge his indebtedness to Professor E. O. Essig, under whose direction these studies have been carried out, for suggestions and advice, and for the reading and correction of the present paper; to Dr. E. C. Van Dyke and Dr. S. F. Light for suggestions and the reading of the manuscript; to Professor H. S. Smith and Mr. S. E. Flanders who provided the original stocks of both the parasite and host, and to Mr. J. F. Lamiman for suggestions in connection with technique.

HISTORY OF THE PARASITE

Habrocytus cerealellae (Ashm.) belongs to the hymenopterous superfamily Chalcidoidea, family Pteromalidae, and the subfamily Pteromalinae. It was originally described by Ashmead (1902) as *Catolaccus cerealellae,* the type being bred from specimens of *Sitotroga cerealella* (Olivier) taken by Mr. Dunwoody in Philadelphia and reared by the United States Department of Agriculture, Washington, D.C.

Kurdjumov (1913) considers that Ashmead's classification of the subfamily Peteromalinae is a step backward as compared with that of C. G. Thomson (1878), Ashmead's being based on the difference in the number of teeth on the right and left mandibles. This character, according to Kurdjumov, is not always constant, even within the limits of one species. In all the specimens of females of *H. cerealellae* (Ashm.) examined by the writer, the left mandible had three teeth and the right four.

Ashmead (1904) places the genus *Catolaccus* in the tribe Peteromalini, the distinguishing character being the presence of four teeth on both mandibles, so that on this character alone the species was wrongly placed in the genus *Catolaccus.* According to Ashmead's (1904) classification, the species must fall in the tribe Rhaphitelini, in which the genus *Habrocytus* Thomson occurs.

Kurdjumov (1913) states that, in connection with the genus *Catolaccus,* Ashmead misunderstood Thomson's description and that therefore none of the American species described under this generic name really belong to it but are either *Habrocytus* Thomson or *Zatropis* Crawford. Viereck (1916) describes the parasite, using *Pteromalus* (*Catolaccus*) *cerealellae* (Ashm.) to designate the species. Girault (1917) uses *Habrocytus cerealellae* (Ashm.) and lists the characters necessary to separate it from nine other species of this genus occurring in North America.

Of the genus *Habrocytus* Thomson, Kurdjumov (1913) states that it includes many different types of Pteromalinae and is unquestionably artificial, the knowledge of this group being rather poor.

The genus is of wide distribution, including primary parasites of many Lepidoptera, Coleoptera, and Diptera. In addition many species have been recorded as hyperparasites of various hymenopterous

parasites, while one species, *Habrocytus medicaginis* Gah., has been recorded as a primary parasite of the clover seed chalcis, *Bruchophagus funebris* Howard, in the United States (1916).

The only recorded host of *Habrocytus cerealellae* (Ashm.) is the Angoumois grain moth, *Sitotroga cerealella* (Olivier); this moth, which belongs to the family Gelechiidae, being a cosmopolitan pest of various grains, both in the field and in storage.

Stanley E. Flanders informed the writer that he saw this parasite puncturing potato sprouts with its ovipositor at the Citrus Experiment Station, Riverside. These sprouts were being utilized for the propagation of mealybugs and were infested with the potato tuber moth, *Phthorimaea operculella* (Zeller), the mining larvae of which were doubtless attracting the attention of the parasite.

LABORATORY METHODS

The studies were carried out in the laboratory which was heated throughout the winter, the temperature ranging from a little over 60° F to 75° F; more exact observations were made in a heated chamber where the temperature was more or less constant at from 75° F to 77° F.

The original stocks of both host and parasite were obtained from white corn. In addition to *Habrocytus cerealellae* (Ashm.), the material was found to contain at least two other species of parasites and a predaceous mite. The mite fed freely on the eggs and larvae of both host and parasite, so it became necessary to breed pure stocks of both of them. As both host and parasite fed within the grain, numerous dissections of the corn grains were necessary, involving, frequently injury to eggs and larvae.

Wheat was therefore substituted: being softer, it was much more easily dissected. The host moths reared from wheat were much smaller than those reared from corn, this food supply being more limited. The host larva usually ate out the entire contents of one side of the grain and then pupated, rarely penetrating through to the other half of the kernel.

The wheat was sterilized in an autoclave. Meanwhile moths emerging from the infested grain were confined in a tin container six inches in length, with a diameter of four inches, one end of which was replaced by a layer of fine copper screening. This was rested on a petri dish and narrow strips of cardboard closely pinned together

were inserted into the tin. The moths readily deposited eggs between the two layers of cardboard and on the floor of the petri dish through the copper screening.

The eggs were collected and examined under a binocular microscope in order to insure freedom from mites and were then transferred to the sterile wheat in glass battery jars, eight and one-half inches in height and six inches in diameter. The tops of these jars were covered with fine muslin and around the outside an extensive layer of vaseline was always maintained in order to prevent mite invasion.

The adult parasites were kept in a refrigerator, being withdrawn and placed with the infested wheat when the host larvae were sufficiently advanced.

Fresh batches of grain were infested with *Sitotroga cerealella* (Olivier) throughout the course of the work so that supplies were always available for experimental purposes. A series of these battery jars was continuously maintained, and after a period of seven months the original jars still contained small stocks of both host and parasite; sufficient host larvae apparently escaping parasitism to emerge as moths and reinfest any remaining sound grains.

For more precise experimental work a series of petri dishes, as recommended by Imms (1929), were used. These were of three sizes: large ones, 14 cms. in diameter, in a single one of which, it was possible to rear as many as 4000 adult moths; medium size, 10–11 cms. in diameter; and small ones 6 cms. in diameter. In this way exact records of infestation and subsequent parasitism could be maintained and it was also possible to watch the oviposition and general behavior of the adults under the binocular microscope without removing the lids or disturbing the parasites in any way.

Throughout the work two general methods were adopted. In the first case, parasites were introduced into the dishes containing the infested grain for standard periods of time, after which they were removed and the dishes incubated at constant temperatures, in order to obtain data on the life-cycle; in the second case periodical grain dissections were carried out for the study of the larval stages.

It was found, however, that by dissecting out the larvae of *Sitotroga cerealella* (Olivier) and placing them, together with female parasites, in tiny flat-bottomed tubes, 3 cms. in length, the latter readily deposited their eggs. The host larvae thus parasitized were removed to small petri dishes, and, provided a fairly high humidity was maintained, the parasite could be induced to pass through its

entire life-cycle quite free of the grain. By this means it was possible to make much more complete observations on the larval behavior than when the results of grain dissections alone were utilized. The length of the life-cycle in the exposed larva was apparently the same as that of a parasite which passed the entire life-cycle within the grain. The parasite larvae could be readily transferred from point to point with a camel's hair brush, without showing any ill effects.

The eggs and early larval stages of this small parasite are of such a delicate nature that very specialized technique is necessary in order to secure slide mounts free from distortion. The use of alcoholic fixatives or stains, or the final use of either euparal or balsam, invariably produced distortion.

The use of Berlese's fluid, as recommended by Imms (1929), into which the eggs or minute larvae were dropped alive, generally speaking gave the best results, some excellent mounts being thus obtained. The use of DeFaure's fluid invariably produced distortion. Some good mounts of first-stage larvae were made by using glycerin jelly, but with this, as with Berlese's fluid, there was a remarkable lack of uniformity in the results, some first-stage larvae shriveling up completely, others giving excellent mounts. With both these mounts the tracheal system showed up to advantage a short time after mounting.

Although the Berlese's fluid was freshly prepared, it crystallized in many slides several months after mounting, yet the writer has slides of hymenopterous larvae which were mounted in this medium in England over eighteen months ago, which are still in excellent condition.

All these media are too clear to show well the distribution of fine setae and it was found that the addition of a few crystals of iodine to the Berlese's fluid gave greatly improved results. Temporary mounts in congo glycerin, as recommended by Kingsbury and Johannsen (1927), were also prepared with some success.

The dropping of larvae into almost boiling 95 per cent alcohol fixed them in a distended condition, suitable for the study of external characters, but made them too brittle for any other purpose. The preservation of larval and pupal stages in 80 per cent alcohol to which five parts of glycerin had been added, retained them in a normal flexible condition for future study.

Larvae of various stages were found to remain alive in a drop of glycerin for many hours and this was sometimes very useful for purposes of general study.

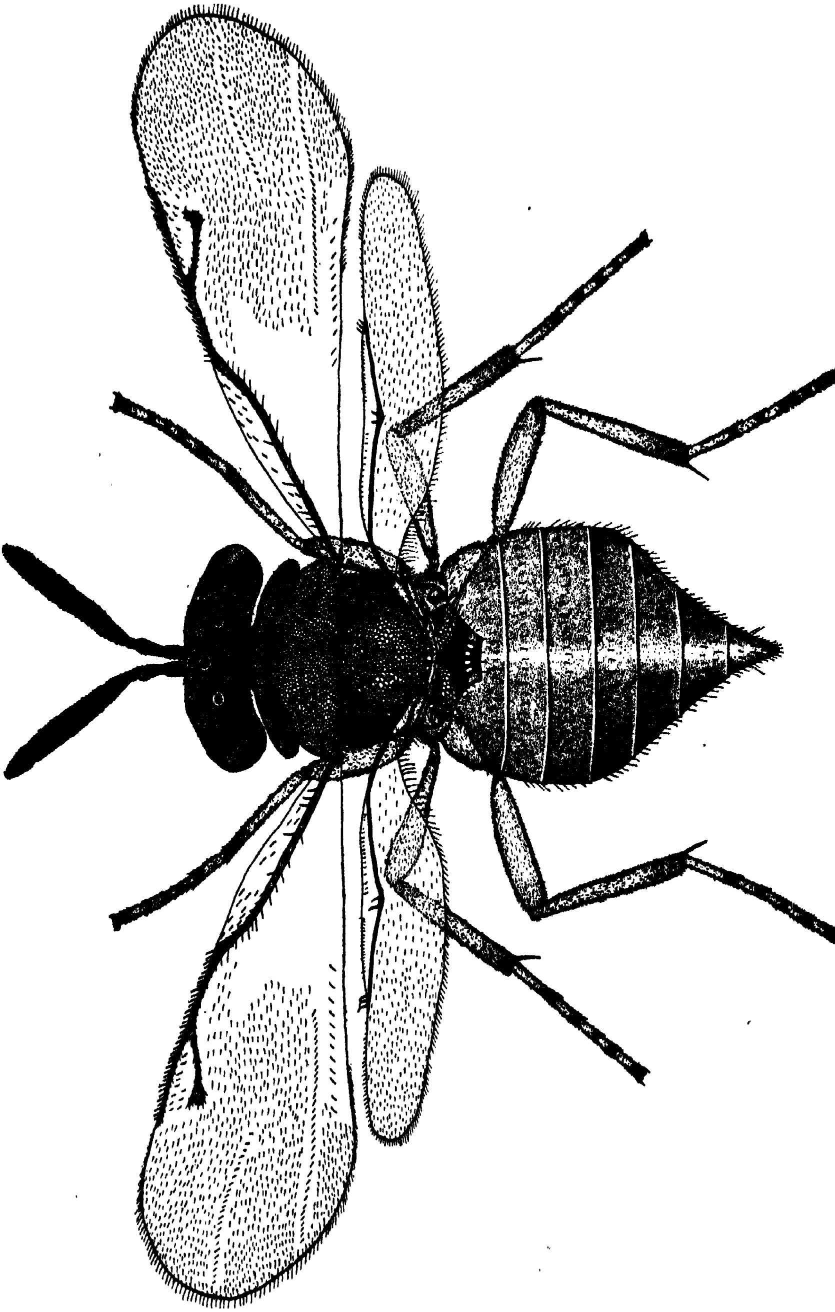


Fig. 1. Habrocytus cerealellae (Ashm.), adult female. × 49. (Actual length 3 mm.)

For the mounting of cast skins and detached mouthparts, De Faure's fluid was used with success. The larva to be examined was mounted facing upward in a drop of the solution on a slide, beneath a binocular microscope. The last anal segments were then torn open with the point of a fine needle and the abdominal contents pressed out. The drop was allowed to dry with the mouthparts orientated for study. A coverglass was superimposed and a small quantity of the mounting medium run under the slide. Slides prepared in this way showed to advantage the mandibles, sensillae surrounding the mouth, the head capsule, and the tentorium.

The larger and more readily handled larvae could be treated with dilute potash to remove the stomach contents, followed by any of the usual methods, and stained with magenta or haematoxylin to show the distribution of setae.

MORPHOLOGY

The Adult

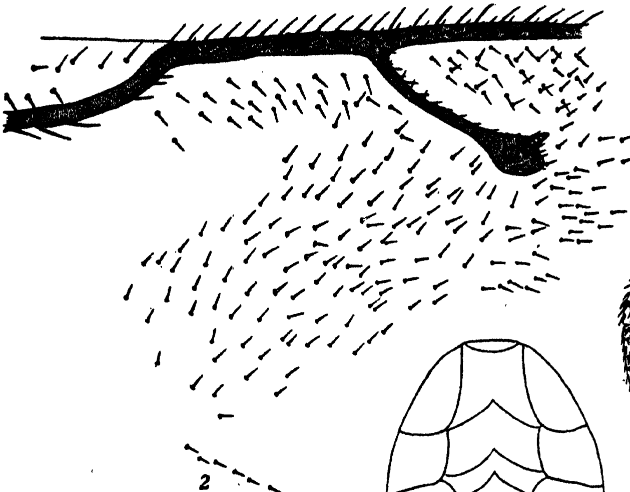
Technical description.—The following is Ashmead's original description:

Female.—Length 2 to 2.5 mm. Metallic bronze green, closely punctate and sparsely pubescent. The abdomen is conic-ovate, and usually, but not always a little longer than the head and thorax united, the two or three basal segments tinged with cupreous, the segments subequal in length, with some very delicate transvere aciculations.

The legs are metallic green, the knees, tibiae and tarsi, except the last joint, the scape of the antennae and the labial palpi being honey yellow; the maxillary palpi and the rest of the antennae are dark fuscous; the flagellum is very slightly and gradually thickened towards the apex, the ring joints annular, the first joint of the funicle being usually a little longer than the pedicel or as long, the following joints very gradually shortening to the club, the last being obtrapezoidal in outline, a little wider at the base than at the apex, the joints of the club, or at least the first two, are wider than long. The head is transverse, wider than the thorax or about 3½ times as wide as thick antero-posteriorly, thinnest at the middle. Wings hyaline, the veins light brown or brownish yellow. The metathorax is impressed on each side posteriorly with usually a short delicate median carina on the middle lobe at base.

Male.—The male measures scarcely 2 mm. in length, bronzed black, the flagellum being filiform and densely hairy, while the abdomen has a yellow median spot basally and is oblong-oval, not pointed at the apex.

The adult female is shown in figure 1.



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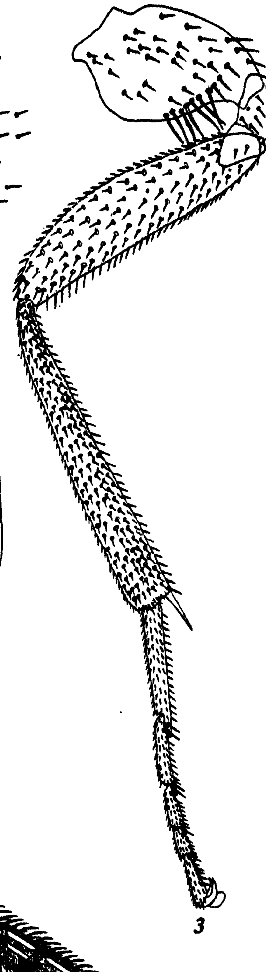

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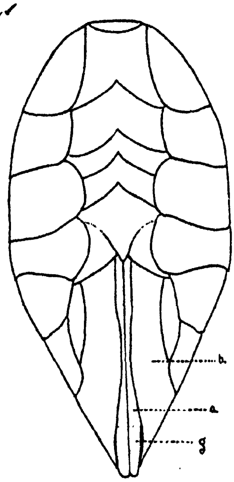

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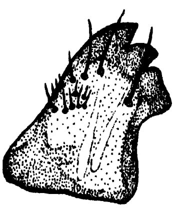

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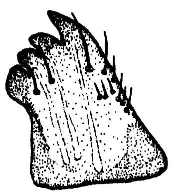

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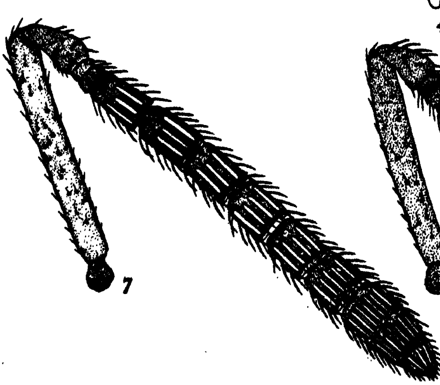

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Fig. 2. Portion of front wing of female. × 195.

Fig. 3. Hind leg of female. × 130.

Fig. 4. Ventral view of abdomen of female; × 80; *g* = ovipositor guard of left side, *a* = inner ovipositor plate, *b* = outer ovipositor plate.

Fig. 5. Left mandible of female. × 195.

Fig. 6. Right mandible of female. × 195.

Fig. 7. Antenna of female. × 195.

Fig. 8. Antenna of male. × 195.

The writer measured 50 males and 50 females with the following results:

	Length in millimeters		
	Minimum	Maximum	Average
Females	1.65	3.75	3.10
Males	0.95	3.00	2.27

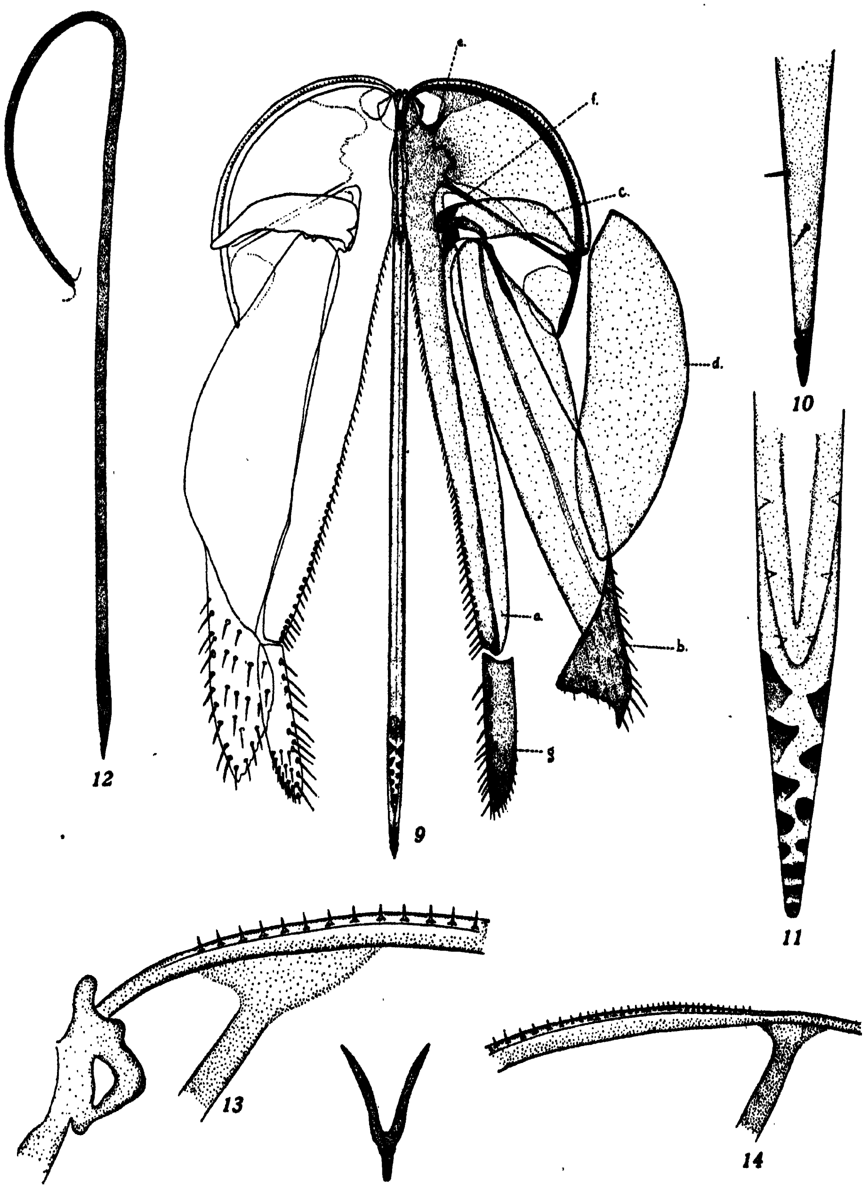
There is considerable variation and overlapping of size, some specimens of both sexes, being larger than the types. Also, very minute individuals of both sexes were reared. These will be further discussed under Biology.

General morphological characters.—Portions of the wing, the two mandibles, the hind leg, and the antenna of the female are shown in figures 2 to 8, together with the antenna of the male. These illustrate various points brought out in the original description. The elongate sensillae are distributed along the segments of the antennae in both sexes, growing more numerous toward the tips, being particularly abundant on the club in the female. This concentration is possibly connected with the behavior of the female in searching for infested grains, as she brings only the tips of the antennae into contact with the outer surface of the grain, and by means of these antennary sensillae is able to detect the presence of host larvae. These sensillae also appear to play a part in the activities of both sexes prior to fertilization, the details of which will be described later.

The ovipositor.—The ovipositor is in close apposition with the ventral surface of the abdomen, extending from its tip to the first abdominal segment, so that, though quite long, it is not easily distinguished. It consists of the stylet sheath and the two stylets, the three together constituting the hollow tubular organ called the sting or terebra, down which the eggs and glandular secretions pass. Associated with the ovipositor are a series of chitinous plates (fig. 9).

The structural details of the ovipositor and its accessory plates have been carefully studied by Imms (1918) in *Blastothrix britannica* Gir., a chalcid parasite of *Lecanium capreae* (Linn.), and the various homologies in the case of *Habrocytus cerealellae* (Ashm.) can be readily worked out, detail of structure alone showing some divergence.

The stylet sheath represents the fusion of two original gonapophyses, the line of fusion being visible along the greater part of the



(*For explanation of figures see bottom of page 321*)

sheath, its tip alone being fused to form a single fine sharp piercing organ bearing a series of backwardly directed barbs. In section it is more or less semicircular, being open ventrally. The two stylets are separate and are held in position within the grooved edges of the sheath, forming together the ventral part of the ovipositor. Each stylet terminates just before the tip of the sheath, their ends being finely pointed and bearing two fine barbs. There are also a number of setae present projecting from the lower part of the stylets (fig. 10).

The two components of the stylet sheath are fused right up to the base of the first abdominal segment. Here they expand into two thickened areas of chitin and then the two components become separated into two divergent arms, which pass immediately into the abdomen and extend up dorsally and curve over within the body cavity, gradually curving downward and inward toward one another until their tips again lie close together near the ventral surface of the body, within the fourth abdominal segment.

The stylets also extend back into the body cavity, each lying in the groove of the corresponding sheath arm, being partly held in position by an extensive series of fine chitinous spines extending out from the sheath arms. A total of 72 such spines were counted on each arm figured. They become shorter and closer together toward the extremities of the sheath arms, being entirely absent from the end section (figs. 13 and 14).

Intimately associated with the ovipositor is a series of paired chitinous plates. An inner pair of elongate plates (fig. 9*a*), extend along the ventral surface of the abdomen and closely overlie the ovipositor, being themselves covered over anteriorly by the sternites of the first five abdominal segments.

From these plates two fine bands of chitin extend anteriorly (fig. 9*e* and *f*) and stretch upward into the body cavity to the divided sheath arms with which they are closely connected, thus keeping them

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Fig. 9. Ovipositor and associated plates, showing the stylet tips exserted beyond the end of the sheath. × 140. *a*, inner ovipositor plate; *b*, outer ovipositor plate; *c*, fulcral plate; *e* and *f*, chitinous bands extending from the inner plate to the arm of the ovipositor sheath.

Fig. 10. Tip of stylet. × 720.

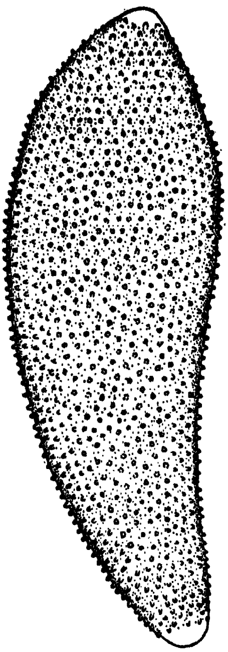
Fig. 11. Tip of sheath showing barbs. × 720.

Fig. 12. Stylet. × 140.

Fig. 13. Basal section of sheath arm showing chitinous teeth. × 600.

Fig. 14. Arm of stylet sheath near its termination showing the teeth less strongly developed. × 600.

Fig. 15. "Y" shaped chitinous structure which overlies the sheath arms basally. × 140.



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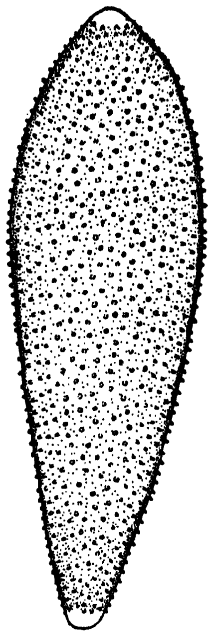

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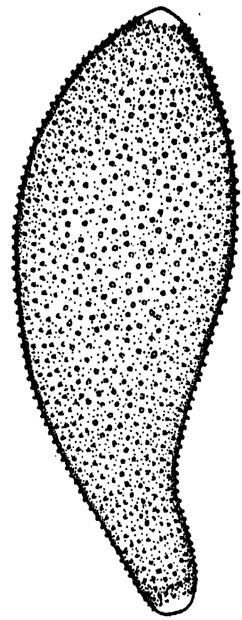

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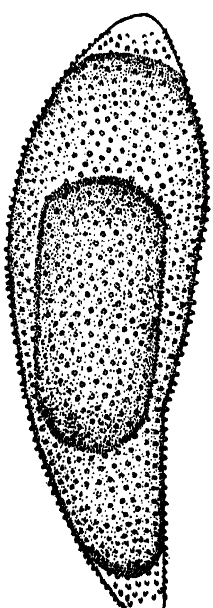

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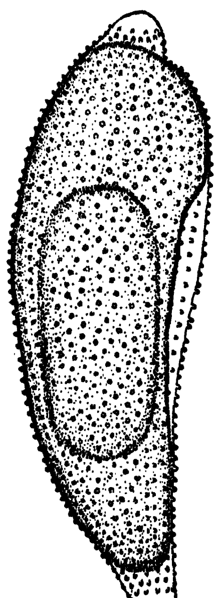

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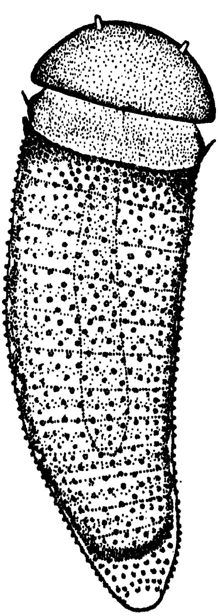

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perfectly rigid. At its distal end each plate bears a palp-like process or ovipositor guard (fig. 9*g*), which projects beyond the tip of the abdomen, covering the ovipositor and being in close proximity to the last abdominal segment.

A second series of shorter and broader plates (fig. 9*b*) lie outside of and partly overlap the first pair. These extend posteriorly and are closely fused with the tergite of the last abdominal segment.

Anteriorly there is a third pair of small triangular plates (fig. 9*c*) which Imms (1918) terms the "fulcral plates." These articulate with a chitinous process on both plates *a* and *b* and a third chitinous process is closely attached to the end of each stylet.

During oviposition, any movement of the elongate plate is translated to the fulcral plate, which in turn acts on the end of the stylet and causes it to move down the sheath so that the stylets may project ventrally beyond the tip of the sheath; the total distance they can thus project being governed by the total length of the divergent sheath arms within the abdomen. By this device the insect has added considerably to the length of the stylets without the necessity of exposing the ovipositor beyond the end of the abdomen to any extent.

There is also a fine Y-shaped chitinous structure which is located at the base of the sheath just at the point where it begins to diverge, each arm of the Y overlaying the sheath arm for a short distance along its course (fig. 15).

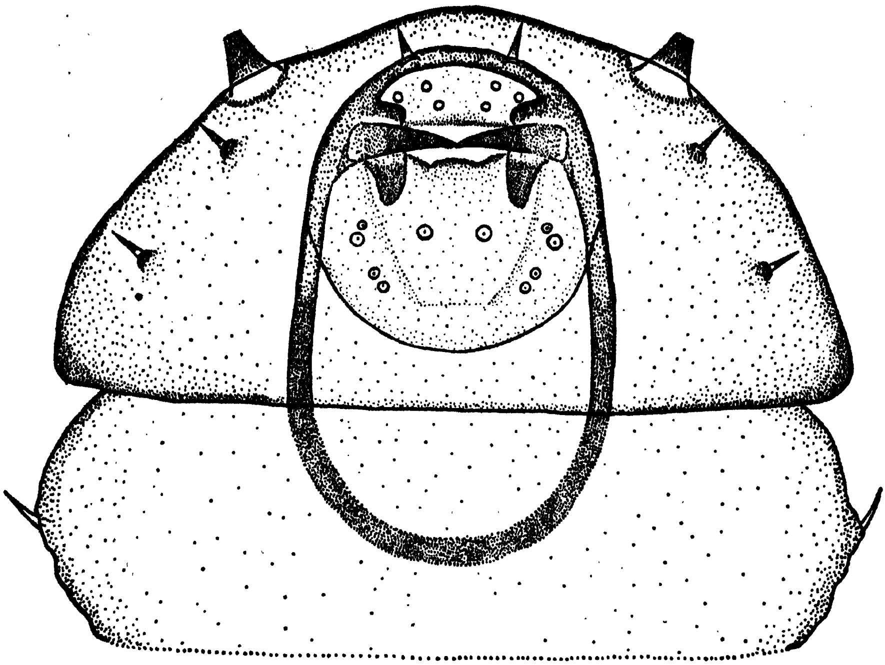
Another series of elongate chitinous plates (fig. 9*d*) lie outside the plates (*a*, *b*), partly covering the latter and also the fulcral plates, and forming part of the ventral body surface.

In figure 9, the stylets are shown projecting beyond the tip of the sheath and it will be seen that the fulcral plate has moved a corresponding distance forward along the sheath arm.

THE EGG

The egg is grayish white, elongate, slightly curved with rounded ends; the cephalic end being rather wider than the posterior end. The average length of 50 eggs was .475 mm. with an average width at the widest zone of .157 mm.

Fig. 16. Lateral view of egg. × 210.
Fig. 17. Dorsal view of egg. × 210.
Fig. 18. Lateral view of egg. × 210.
Fig. 19. Developing embryo within the egg. × 210.
Fig. 20. A later stage in embryo development. × 210.
Fig. 21. The newly hatched larva crawling out of the egg. × 210.



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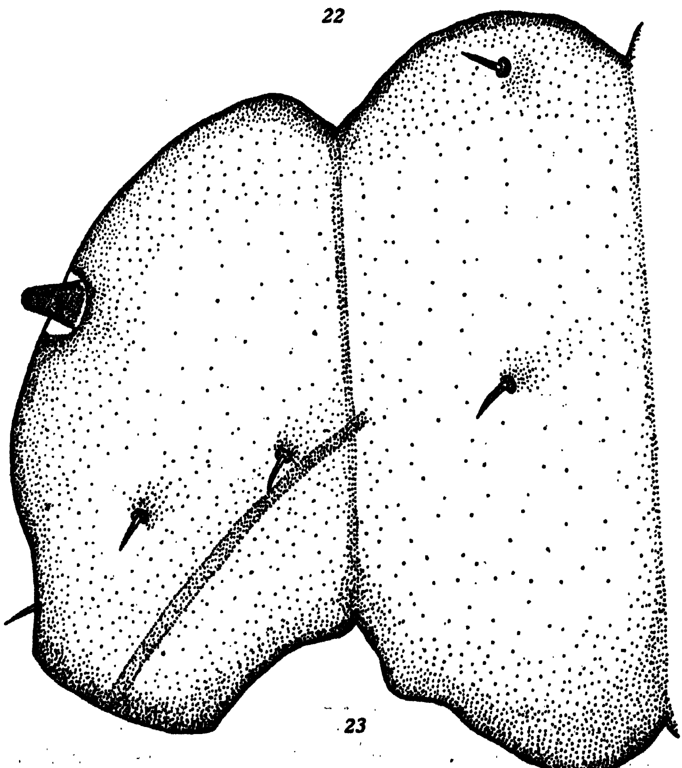

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Fig. 22. First stage larva, ventral view of head. × 920.
Fig. 23. First stage larva, lateral view of head. × 920.

The entire surface of the chorion, except at the ends, is armed with an extensive series of fine spines. In this and in its general structure, it resembles the egg of *Dibrachys boucheanus* (Ratz.) figured by Parker (1924).

The maximum length of all eggs examined was .613 mm., the minimum being .409 mm., while the width varied from a maximum of .170 mm. to a minimum of .136 mm. There is frequently a variation in the length, width, and shape of the eggs laid by the same female, the length varying from .613 mm. to .477 mm. and the width from .170 mm. to .136 mm. Some eggs are considerably narrower and more curved at the posterior end, while less frequently there is a prominent narrow tip at the cephalic pole. Figures 16 to 18 show variations in three eggs deposited by the same female.

The diameter of the egg and the ovipositor.—The width of 33 eggs laid by one female varied from 0.15 mm. to 0.17 mm. at their widest point, while the external diameter of the ovipositor was .032 mm. In a second case the width of the ten eggs varied from 0.14 mm. to 0.17 mm., while the external diameter of the ovipositor was .030 mm.

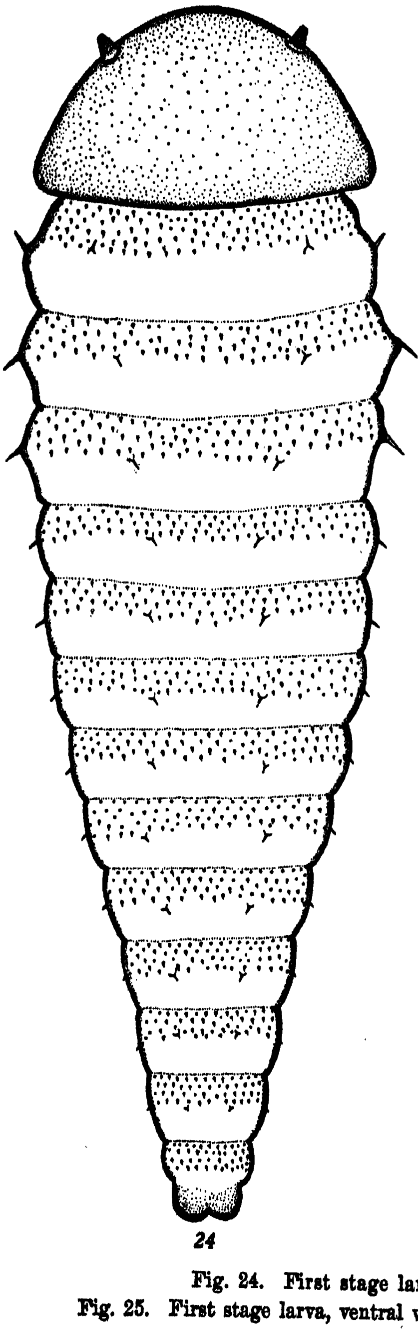
The diameter of the passage down which the eggs pass would be considerably less than .03 mm. and yet the eggs are as much as five times the external width of the ovipositor, so that they must undergo considerable compression during their passage down the ovipositor tube.

The Larva

In describing the various larval stages, the writer has eandeavored to follow the general method of Parker (1924), using his work as a guide.

No measurements have been quoted for intermediate stage larvae. The great variation in the size of the mature larva is reflected in the intermediate larval stages, so that the statement of size of a limited number of intermediate stage larvae would have little significance. A small number of larvae were kept under close observation throughout their entire larval life, accurate measurements being made immediately preceding and immediately following ecdysis, but it has been considered advisable to include these in the section on the biology of the larva.

Stage I. The first-stage or *primary larva* immediately after hatching is clear and translucent, except for a narrow central zone which has a greenish tinge owing to the presence of greenish colored drops of liquid in the alimentary canal. The length averages .412 mm., with



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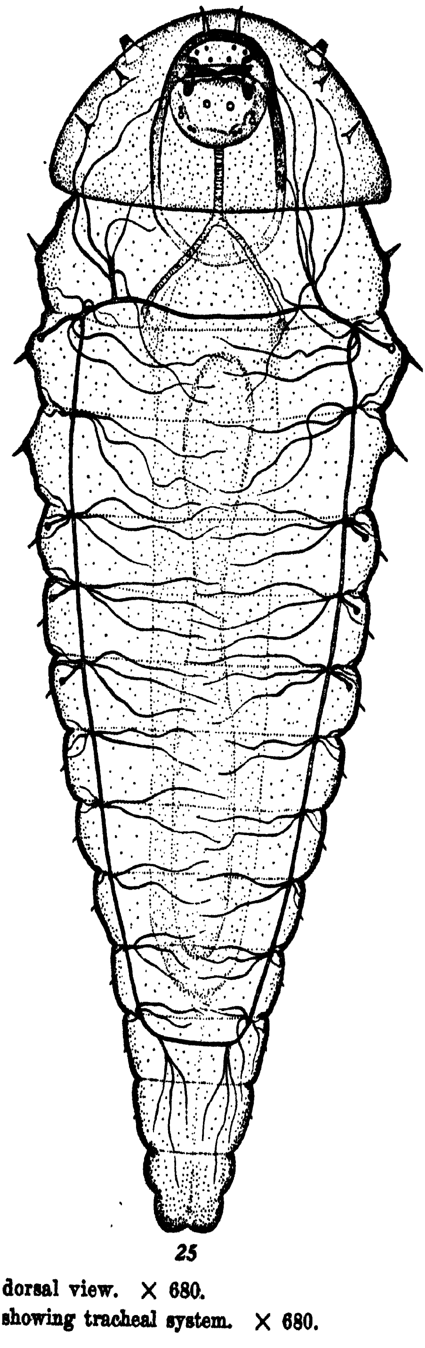

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Fig. 24. First stage larva, dorsal view. × 680.

Fig. 25. First stage larva, ventral view showing tracheal system. × 680.

a maximum of .460 mm., and a minimum of .374 mm.; the length being in part determined by the length of the egg from which it emerges, the larva always being a little shorter than the egg. The average width of the body at its widest point is .132 mm., with a maximum of .140 mm., and a minimum of .123 mm.; the head being slightly wider.

The larva consists of a prominent head and 13 segments. The three thoracic segments are fairly even, the body segments narrowing posteriorly. Dorsally and laterally each segment bears a pair of setae which decrease in size in the posterior segments. The setae on the first segment of the thorax are directed anteriorly and those on the remaining segments posteriorly. In addition, surrounding each segment is a series of very fine spines visible only at high magnifications (figs. 24, 25).

The head is more or less semicircular in outline, slightly more heavily chitinized than the body, and bears a pair of truncate antennae dorsally. The mouth is ventral and is surrounded by a short rounded, tubular structure formed from the integument, this being very conspicuous as the larva elevates the head, when crawling along (fig. 23). On the ventral surface of the head are three pairs of long setae, one pair in front of the mouth and two pairs at the sides. The mouth is surrounded anteriorly by a curved band of chitin, which Parker (1924) terms the facial arc. A semi-circular raised band of the integument extends from the facial arc behind the mouth, the two forming a more or less circular outline which encloses all the mouth parts.

The mandibles are deep amber in color, long and narrow, slightly curved, and averaging .022 mm. in length. Dissected out and in side view they exhibit a much more pronounced curvature. They are supported dorsally by two bands of chitin constituting part of the facial arc and ventrally by two other chitinous bands which Parker (1924) terms the mandibular apophysis, while passing back in the head and projecting into the thorax dorsally there is a fine elongate band of pale colored chitin termed the tentorium, which unites the two sides of the head capsule. Above the mouth are three pairs of fine sensorial organs and below are five pairs (fig. 22).

The respiratory system consists of two main tracheal trunks, one extending along each side of the body, being united anteriorly and posteriorly by transverse commissures in segments one and eleven. The main trunks pass forward into the head and backward into the

last abdominal segments, where they divide into many smaller branches. From the main trunks four pairs of short branches lead respectively to four spiracles on segments two, four, five, and six. In addition each main trunk gives off dorsally and ventrally a series of branches which divide freely and pass into the various body organs (fig. 25).

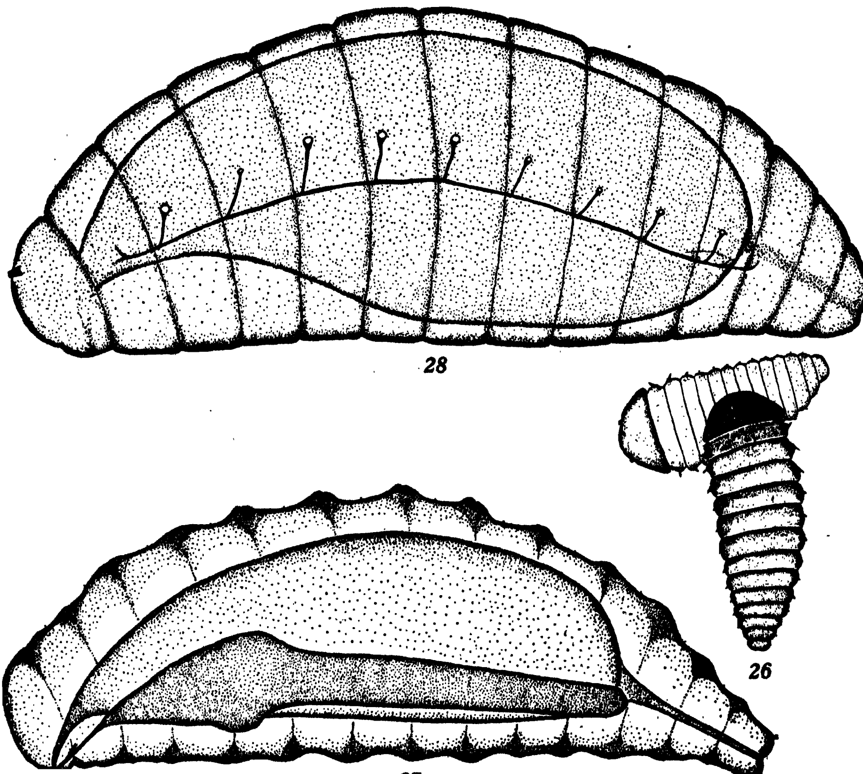


Fig. 26. First stage larva feeding on another first stage larva. × 170.
Fig. 27. Mature larva showing the alimentary tract and salivary glands. × 73.
Fig. 28. Second stage larva. × 242.

Stage II. The *second-stage larva* is grayish green in color and is now slightly curved in outline, the body segments decreasing in size anteriorly to the head and posteriorly. The head is very much less conspicuous than in the freshly hatched larva, being much narrower than the widest abdominal segments.

The fine spines visible on the anterior of the body segments of the first stage larva are missing in this stage. Dorsal and lateral spines are present on the body segments. The mandibles now appear to be almost straight with sharp heavily chitinized tips. Their average

length is .032 mm. There has been a notable change in the tentorium, which is now almost as wide as long, with a flattened base. The arrangement of the sensillae around the mouth appeared to be the same as those of the mature larva.

Immediately after moulting, only four spiracles appeared to be open on segments two, four, five, and six, but toward the end of the

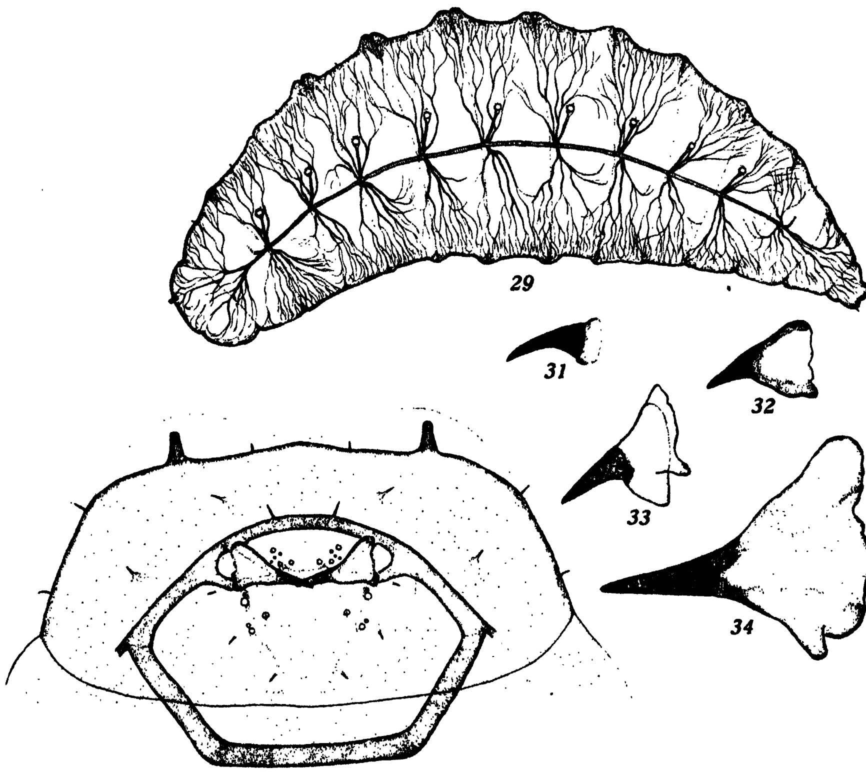


Fig. 29. Mature larva showing tracheal system. × 90.
Fig. 30. Ventral view of head of mature larva. × 230.
Fig. 31. Mandible of larva stage I. × 1450.
Fig. 32. Mandible of larva stage II. × 1450.
Fig. 33. Mandible of larva stage III. × 1450.
Fig. 34. Mandible of larva stage IV. × 1450.

second stage five others appear to develop on segments three, seven, eight, nine, and ten; those on segments two, four, five, and six being the larger (fig. 28).

Stage III. The *third-stage larva* differs little from the second stage except in size and also it is slightly more curved in outline. The mandibles increase to an average length of .044 mm. and are more triangular in outline, being very slightly curved. The tentorium has

again become shorter in proportion to its width, representing an intermediate stage between that of stage II and the mature larva or stage IV, while the sensillae around the mouth appear to be the same as those of stage II and the mature larva.

Stage IV. The *mature larva* (fig. 29) varies from light to dark gray in color, being cylindrical and arched in outline, narrowing toward both ends. There is great variation in size, the average length of 50 individuals being 2.81 mm., with a minimum of 1.55 mm., and a maximum of 4.10 mm.

The width of the body at its broadest point is always about one-third of the total length. It consists of a head and thirteen segments, with conspicuous dorsal ridges at the junctions of the segments, particularly in the median zone. The integument is smooth and glistening, being armed with a series of spines; dorsal, lateral, and ventral spines being present on some segments. There are six prominent spines on the end of the last abdominal segment, all directed posteriorly, four of these being dorsal and two ventral. There are nine spiracles, one on each segment of numbers two to ten inclusive. There is also a short trunk leading from the main longitudinal trunk in segment eleven which terminates before reaching the integument. Transverse commissures unite the two main longitudinal trunks in segments one and eleven, profusely branching tracheae passing out from the main trunk to the various body organs (fig. 29).

The head is inconspicuous, being about half the width of the broadest abdominal segments. It is more or less semi-circular in outline with two prominent rounded zones, one on each side, below which lie the antennae which are more or less cylindrical, long and narrow, and pigmented a deep amber color. The mouth is ventral and is located on a slight protuberance. Three pairs of setae lie on the ventral surface of the head, one pair above and two pairs at the sides of the mouth. There are also two pairs of lateral setae on the head, with an additional pair between the antennae. The mandibles have increased in size considerably, averaging .067 mm. in length. They are triangular in outline with a single sharp, heavily chitinized tip, the chitinization being less heavy toward the base.

Above the mandibles and below the facial arc there are six pairs of minute sense organs, while below there are at least eight pairs, three pairs being in the form of fine spines. The tentorium is well developed, being now much wider than long, with a broad flat base which projects into the thorax (fig. 30).

BIOLOGY

The Adult

Length of life.—Twenty-five individuals in glass tubes 4½ inches long were placed in an incubator at from 75° F to 77° F, the end being loosely plugged with dry absorbent cotton. The relative humidity was apparently very low. The average length of life of 10 females under these conditions was 6.6 days, with a maximum of 8 days, and a minimum of 6 days; the average length of life of 15 males being 6 days, with a minimum of 4 days, and a maximum of 8 days.

One hundred and sixty individuals were kept under similar conditions, except that the absorbent cotton was kept moistened with ordinary tap water. There was a great increase in the length of life. The average length of life of 68 females was 14.38 days, with a minimum of 9 days, and a maximum of 27 days; the average for 82 males being 9.16 days, with a minimum of 3 days, and a maximum of 19 days.

A further series of 20 was incubated under similar conditions, but instead of water a mixture of honey and water was kept constantly on the absorbent cotton. The average length of life of 7 females was 41.14 days, with a minimum of 37 days, and a maximum of 46 days; while the average life of 13 males was 31.84 days, with a minimum of 20 days, and a maximum of 38 days. Both sexes fed freely on this sweetened liquid and though only a limited number of individuals were used in the test, it is evident that the provision of sweetened liquid led to a remarkable increase in the length of life.

Records of the length of life of ten females were also obtained, five being kept constantly in small tubes with exposed larvae and five in infested grain, no moisture of any kind being provided. The average length of life of the five individuals with exposed host larvae was 22.8 days, with a minimum of 17 days, and a maximum of 26 days; while the average length of life of the five individuals in the infested grain was 19.6 days, with a minimum of 14 days, and a maximum of 28 days. Some, if not all, of these females fed on the liquid which exudes from the punctures made in the host larva by the parasite prior to oviposition.

Approximately five hundred parasites were forwarded from Riverside, arriving at Berkeley on August 29, 1930. They were fed on

honey and water for several hours and then divided into two groups, one group being maintained at a constant temperature of 48° F and the second at a temperature varying from 42° F and 46° F.

The last individual of the first group died 49 days after being placed in the constant-temperature room. At this time there were still 20 females alive in the group kept at from 42° F to 46° F, eight of these being still alive 60 days after being placed in this cool room. On examination ten days later, all were dead.

A second batch which emerged on September 27, 1930, were placed in a cool room with the temperature varying from 42° F to 46° F. At the end of 21 days a number of males were dead but all the females were alive. At the end of 31 days the majority of the males and a few females were dead, but the majority of the latter were still alive.

At the end of 53 days there were still approximately 40 per cent of the original number alive, including a few males. On this day they were all transferred to the laboratory and utilized to parasitize host larvae.

From these various tests it is evident, that the provision of sweetened solutions add to the length of life of both sexes and that they can be kept alive for considerably longer periods by keeping them at low temperatures. It is also clear that under all conditions the male lives for a shorter time than the female.

Reaction to temperature.—At a temperature of 42° F they are extremely sluggish but if disturbed will crawl slowly around in the container. Removed to a temperature of 65° F they become active in a few minutes, running and flying readily. They are quite active and oviposit freely at a temperature of 65° F. At 76° F they are even more active, running and flying rapidly and ovipositing freely. They are not, however, strong flyers, settling quickly after a short flight in the laboratory.

Reaction to light.—In a general way they are positively phototrophic, tending to concentrate on the side of the container nearest the source of light. If enclosed in a dark container such as a cardboard carton, the puncturing of a small hole in the side will cause all the individuals to come out of the container in the space of a few minutes. If a light is turned on in the laboratory at night, all the parasites will be found to be resting immobile on wheat grains or on the sides of the container, but they soon begin to crawl around and, with the light on, have been seen to oviposit freely at 10 P.M., the temperature then being between 60° F and 70° F.

Food requirements.—It has been pointed out in connection with the length of life of the adults that they require semi-liquid food of some kind, whether it be sweetened water or part of the fluid contents of the host larva apparently making little difference; adults provided with neither of these substances having a much reduced life. It was evident that the relative humidity of the atmosphere in the heated chamber was low and the provision of moistened absorbent cotton in order to raise the humidity probably played a part in lengthening the life of the adult.

The feeding habits of the adult female will be discussed in more detail in connection with oviposition.

Parthenogenesis.—Female pupae were dissected from grain and placed in a separate container in order to avoid the possibility of fertilization. Upon emergence they were placed in dishes containing grain infested only by the host. These unfertilized females oviposited freely, a total of 298 progeny being without exception males.

Sex ratio.—It was noted that in bulk stocks there always appeared to be a preponderance of females. The total progeny of four females fertilized immediately after emerging from the grain were counted and sexed with the following results:

	Total progeny	Number of males	Number of females	Per cent of males	Per cent of females
Female number 1	93	38	55	40.86	59.14
Female number 2	327	81	246	24.77	75.23
Female number 3	270	61	209	22.59	77.41
Female number 4	324	85	239	26.23	73.77
Total	1014	265	749	26.13	73.87

It is thus evident that in the four cases cited the percentage of females was considerably in excess of that of males, the highest percentage of males being 40.86 per cent and the lowest 22.59 per cent; the percentage for the total of 1014 individuals being—males 26.13 per cent and females 73.87 per cent.

Mating.—From the experimental host stocks on which parasite eggs had been laid at approximately the same time, males invariably emerged first, the subsequent emergences being a mixture of the two sexes right up to the last mergence, the life-cycle of the male being shorter than that of the female. Under normal conditions, however,

there is a general overlapping of the various broods, so that individuals of both sexes are always present in the cultures.

A series of tests indicated that both males and females will copulate within an hour after first emergence.

If an unfertilized female is placed in a small tube one inch in length, together with a male, both may run around the tube for some hours or rest immobile a short distance from one another, the sexual stimulus apparently not being effective unless the two individuals happen to meet. When they do meet the male becomes greatly excited and pursues the female around the tube vibrating his wings rapidly, both running, and flying, in pursuit.

The male suddenly jumps upon the back of the female and runs forward onto her thorax, ceasing to vibrate his wings, and commences to play his antennae over those of the female. If not desiring copulation the female will continue to run around the tube, but if unfertilized she will stop and a few moments after the antennal contact will lower the anterior abdominal sternites. The male almost immediately moves back and grasping the upper sides of the female abdomen firmly with the legs, brings the abdomen down beneath that of the female; then vibrating his wings in order to retain this position, he inserts the tip of the abdomen anteriorly into the genital aperture of the female; this being accessible only when the female lowers the anterior sternites.

Several times it was noted that, in the preliminary maneuvers, the antennae of the male at no time came in contact with those of the female but are played about just in front of the latter, nevertheless the final result was the same.

The time occupied in actual sexual contact varied from five to eight seconds—8, 7, 6, 5, 6, 6, 8, 6, and 8 seconds being the times recorded for nine pairs.

After copulation the female rests motionless on the side of the tube but the male soon commences to run actively around the tube again and on coming in contact with the same female from time to time, jumps upon her back and repeatedly attempts copulation, but the female always runs off and a second contact is never effected.

Females known to have been fertilized shortly after emergence, at various times throughout their adult life were removed, from infested grain where they were ovipositing in the absence of males, and were confined with males in tubes but they never displayed any sexual interest; more than one sexual contact was never observed.

From a single sexual contact lasting 6 seconds, a female produced a total of 327 progeny of which 246 or 75.23 per cent were females, the very last emergences being females. A second female produced a total of 324 progeny of which 239 or 73.77 per cent were females.

PRE-OVIPOSITION PERIOD

Fertilized and unfertilized females placed in with infested grain on the day of first emergence were never observed to oviposit, but moved slowly about the grain, resting immobile for long periods. The day following emergence, however, there was greatly increased activity, all females ovipositing freely so that there appeared to be a pre-oviposition period of 24 hours.

A female dissected immediately on emergence showed a number of eggs developing but none approaching maturity. Six hours after emergence several eggs were found approaching maturity, but not yet quite full size. Dissection of a female 24 hours after emergence showed the presence of several mature eggs, while the dissection of a female kept isolated in a tube for 48 hours after emerging, revealed the presence of 21 mature eggs, the results bearing out the general observation on the necessity of a pre-oviposition period in order to permit egg maturation.

Oviposition.—When contemplating oviposition the female crawls slowly over the grain containing host larvae, playing the tips of her antennae continuously over the grain surface. In these, numerous sense organs have been shown to be located and with their aid she isolates an infested grain. She then becomes motionless, elevates the entire body temporarily, and deflects the abdomen into a position at right angles to the horizontal, bringing the tip into contact with the grain surface, the ovipositor thus being automatically carried down. The antennae are now held high above the grain surface, more or less motionless. The tip of the ovipositor is then pushed slightly into the grain and the abdomen is drawn back into its normal position, the ovipositor, being thus drawn out from beneath its guards becomes visible for the first time as a fine rod passing down from the base of the abdomen and being more or less at right angles to it.

Having obtained a firm grip on the grain with all six legs, the female endeavors to pierce it with the ovipositor. If the host larva within the grain is maturing it will have eaten out the greater part of the grain contents leaving only a thin outer shell, which the parasite

has little difficulty in penetrating; but when the larva is less mature, the grain to be penetrated is therefore much thicker and the parasite may experience considerable difficulty, often making numerous attempts in various places before succeeding in piercing the grain.

Having penetrated the grain and reached the host larva, the parasite may immediately deposit an egg or she may paralyze the larva prior to ovipositing. The time spent on the grain may thus be only a few minutes, or it may be as long as an hour.

This preliminary paralization of the larva invariably precedes oviposition in the experimental parasitization of exposed larvae and the details can here be more easily observed.

On coming in contact with the exposed larva, the female parasite immediately springs upon it. The larva twists and turns violently in an effort to dislodge the parasite and usually fails. The parasite then runs the tips of the antennae over the surface of the larva, until she locates an intersegmental zone. She then inflexes the abdomen and places the ovipositor in position just as when about to penetrate the grain.

In a maturing larva the female may experience considerable difficulty in penetrating the epidermis, the ovipositor sometimes bending in the middle when the pressure is applied and sliding off the surface of the larva. At other times the upper surface of the host larva may be forced down onto its ventral surface before the integument is penetrated; entry is being accomplished in the intersegmental zone, where the integument is thinnest.

Immediately after penetrating the host larva, the parasite commences to force in the paralyzing fluid. If the container be held before a light, the drops of liquid can readily be seen passing down the ovipositor. At the same time the female continues to force the ovipositor deeper down into the larva and it can be seen clearly within the body of the larva. When finally inserted to its full length, the stylets are forced out beyond the tip of the stylet sheath and are extended, together with the sheath, into the anterior and posterior segments, thus ensuring a general and rapid distribution of the paralyzing fluid.

The larva becomes motionless shortly after the liquid begins to enter its body but the parasite continues to force in more liquid. The time the ovipositor was imbedded varied from four to ten minutes, and several times the parasite was observed to penetrate the larva a second time, though it had remained quite motionless.

Following the ovipositor as it is withdrawn, a fine grayish strand of semi-liquid gelatinous matter from the wound projects from the body surface, the barbs on the ovipositor sheath apparently helping to draw out this material, which is part of the ordinary haemocoele contents. Almost immediately the parasite turns around and begins to feed on this strand. All the mouthparts are extended downward; it crushes the solid matter with the mandibles and absorbs the liquid material. It may feed on this strand for periods ranging from 45 minutes to one hour and a half, all this time being practically motionless with the abdomen resting flat down in contact with the surface of the larva. During this period a very noticeable amount of the host larval body contents may be drawn out through this puncture so that it becomes quite flaccid. Even after many eggs have been laid on a host larva, the same parasite has been observed to pierce the integument and feed on the body fluids.

In larvae within the grain, which are large and consequently near the surface, a similar process may take place; the parasite, after piercing the larva, withdraws the ovipositor and with it part of the host body contents which have become attached to it, through the surface of the grain; this the parasite immediately begins to consume. Apparently in the case of some smaller larvae more deeply imbedded, paralyzation never occurred, the parasite pausing only long enough to deposit an egg.

The process of oviposition can be more readily observed on exposed larvae. The female parasite brings the ovipositor down into the vertical position just as in paralyzation, but, instead of piercing the larva, the ovipositor point slides off and extends down into a ventral position, the abdomen being also slightly depressed, the head and thorax being maintained in their normal position on the dorsal surface of the larva.

The stylets are seen to be extended out beyond the end of the sheath. The parasite remains more or less motionless moving the abdomen slightly from side to side and a few moments later the egg is emitted. The egg passes down the ovipositor and emerges just before the point where the sheath fuses to a solid point. The narrow pole appears first but the entire egg becomes visible almost immediately and slides at least part of the way down the extruded stylets onto the surface of the host larva, to which it becomes lightly attached, being aided by the fine spines on the chorion.

Occasionally an egg may become stuck on the ovipositor; it is then brushed off with the aid of the hind legs. The female sometimes pauses for a few moments to orient the egg with the tips of the stylets, but just as often retracts the ovipositor to the position of rest and crawls off onto the side of the jar.

Practically all eggs are deposited in a ventral position, the ovipositor being frequently curved round to reach the underside of the larva, but this does not seem to affect the passage of the egg. The total time occupied in depositing an egg varied from about ten seconds to a minute or more, the eggs being generally laid singly, though as many as three have been seen to be deposited within a minute.

Normally the parasite on laying an egg crawls off onto the side of the jar for several minutes and then returns to deposit another egg, doing this four or five times and then resting for a few hours before depositing others.

The daily deposition of eggs varied considerably. One female, which deposited a total of 76 eggs on an exposed larval host, laid 4 eggs the first day, followed by 8, 7, 14, 11, 2 and 15 on subsequent days. Another laid a total of 79, 18 being laid on the first day of oviposition, followed by 21, 18, 12 and 10 on subsequent days. Another female laid 19 eggs in a period of six hours.

A female confined with infested grain oviposited for 12 days and 327 progeny emerged—a minimum daily average oviposition of 27.25 eggs per day. Another oviposited for 19 days and 324 progeny emerged—a minimum daily average oviposition of 17.05 eggs.

Period of oviposition.—Oviposition commenced the day following emergence and usually continued until one or two days preceding death. The average period of oviposition of six females was 17.5 days with a minimum of 12 days, and a maximum of 25 days.

Total eggs deposited by single female.—Three females were provided with an unlimited supply of infested grain and the numbers of progeny emerging were counted, thus obtaining a minimum figure for the total oviposition. No allowance was made for non-fertile eggs, larval mortality, or for the deposition of more than one egg on a single host. The total progeny reared from the various females were 327, 324, and 270.

SUPERPARASITISM

It has been found to be quite a common occurrence for a female parasite to deposit on a single host larva a number of eggs greatly in excess of the number which could possibly mature, even if available food were the only consideration. Individual females have been observed to deposit 18, 19, 23, and 32 eggs respectively on individual host larvae in petri dishes, although there were other host larvae in the dish at the time. The stimulus to oviposit outweighs all other considerations: the parasite continues to deposit eggs on the same larva even after the first-laid eggs have hatched, frequently crushing, in her eagerness, both eggs and larvae. Conditions in a petri dish are not natural, but grain dissections showed that superparasitism was quite common, 16, 14, 9, 6, 4, 5, and 3 parasite eggs being dissected from grains containing single host larvae.

In these same dishes many grains contained unparasitized host larvae. Female parasites were apparently unable to distinguish between host larvae parasitized within the grains, females being observed to oviposit in grains which, on dissection, revealed the presence of a maturing parasite larvae, together with host larval remains; while the dissection of the grains revealed the presence of a number of parasite larvae only one of which could mature, the others being still in the early larval stages, yet already dead or dying.

As it was known that generally only one parasite matured and emerged from any one grain, experiments were undertaken to determine the fate of the others in cases of superparasitism. The first parasite larva on hatching has been shown to crawl actively over the host for some time prior to feeding, destroying any other eggs or larvae with which it happens to come in contact. The young larva appeared to crawl about in a haphazard manner, coming upon the various eggs and larvae by chance. This was very obvious in petri dishes, where two small parasite larvae have been observed crawling over the host and finally meeting, both being apparently surprised and momentarily retreating, then returning to attack one another. The first larva to succeed in obtaining a grip on the other at the side in any of the thoracic segments invariably destroyed it; for being grasped in the thoracic region renders the victim impotent, as it is then unable to inflex the head to reach its attacker.

With its sharp pointed mandibles the attacker pierces the delicate integument of the victim; the latter may elevate the anterior segments, thus lifting the attacker temporarily into the air, but the latter never releases its grip and the victim soon gives up the struggle. The attacker then buries the head deeper within the victim and feeds on its body contents, sometimes leaving only the shriveled integument, sometimes crawling away after feeding for only a few moments. Occasionally it returns to the dead larva and may then penetrate the integument on any of the body segments and begin to feed. Eggs are destroyed in a similar manner, part of the contents being devoured. Size is not an advantage in this preliminary struggle, the parasite larva being most active shortly after hatching, and thus quicker to obtain a grasp of the larger and more sluggish individual.

The fate of ten such larvae, all of which hatched within a short time on a host larva, was as follows: Larva x destroyed four larvae; larva y destroyed two, then came into contact with x and destroyed it, x having fed freely and so proving a ready victim. Larva z meanwhile destroyed one larva, came in contact with y and destroyed it; larva z being thus the sole survivor, penetrated the host larva and began to feed upon it.

That one first-stage larva does not always destroy all the other larvae on the host was also demonstrated. Two advanced larvae have frequently been found feeding at the opposite ends of the same host larva. With the increase in the size of the two parasite larvae and the corresponding decrease in the food supply, the two are brought closer together, eventually meeting, whereupon one destroys the other.

That the two sometimes fail to meet was shown from two grain dissections, from one of which three mature parasite larvae were obtained, two of average size and one very small, but all passing into the prepupal stage; the two larger ones subsequently emerged as adults, the smaller one died.

In the second case a parasite pupa was dissected, together with a mature parasite larva, from a grain containing the remains of a single host larva. In both these cases the original host larva was so large that the parasites were able to mature without coming in contact with one another. This destruction of one parasite larva by another of the species seems to be the general rule with solitary parasites.

Voukassovitch (1927) states that a female of *Habrocytus* spp. oviposits on larvae of braconids in Serbia, such as *Apanteles* spp., within their cocoons. The larvae on hatching move actively about on

their host for several hours, feeding at intervals before becoming fixed. During this active period they kill, apparently by injecting poison, all the other eggs and larvae, either of their own or other species they encounter. *Habrocytus bedeguaris* Thoms. and *Torymus macropterus* Wlk. oviposited on the larvae of *Rhodites rosae* and *Oligesthenus stigma* and also on the larvae of their own species in galls of *R. rosae.*

Rimsky-Korsakov (1914) reared *Homoporus vassilievi* Ashm. as a parasite of *Isosoma eremitum* var. *nodale.* The egg was laid, not on the larva of the host, but in the wall of the stem in that internode in which the larva of *I. eremitum* is present.

After hatching, the larvae crawl for one or two days over the body of the host and then destroy one another, the surviving larva killing the host. It was stated earlier that female parasites were several times observed to oviposit in grains in which a parasite larva was already maturing and in which the available food supply was exhausted. Larvae hatching from such eggs would sometimes die of starvation. In two cases, however, the writer dissected out mature parasite larvae on which first-stage larvae were feeding.

A number of first-stage parasite larvae placed on mature parasite larvae in petri dishes invariably ate through the integument and began to feed. The mature larvae normally twist and turn considerably, however, with the result that soonor or later the young parasite is crushed on the floor of the petri dish; within grains they would doubtless be destroyed in a somewhat similar manner.

The mature larva is unable to inflex the body sufficiently to attack the small larva with the mandibles, but should the young larva happen to crawl across the head of the mature larva, as it sometimes does, it would be immediately pierced by the mandibles of the mature larva and destroyed.

One larva which was successfully reared on a mature larva from the time of hatching, finally destroyed it. This larva was much smaller than the larva on which it had fed and the resulting adult was also undersized, yet it does seem possible that on rare occasions this may occur naturally within the grains, although parasite adults could never be induced to oviposit on mature larvae of the species confined in small tubes.

Stages of the Host Parasitized

The larval stages of the host, from an early stage in development right up to pupation, can be parasitized, but no eggs were ever deposited on host pupae.

Host pupae of various ages were confined with parasite females in small tubes but on one occasion only did the parasite female display any interest. The pupa in this case had just pupated, the chitin being still soft and white. The female parasite immediately sprang upon it and inserted the ovipositor into the abdomen between two of the segments, later withdrawing it so as to feed on the extruded contents. This process was repeated a number of times during the day, until the pupa became quite flaccid and finally died, but the parasite deposited no eggs upon it. There did appear to be a preference for the more mature host larvae, very small larvae offering an inadequate food supply.

Of a total of 170 infested grains containing parasitized hosts which were dissected, 123 or 72.35 per cent of the total contained parasites together with host larval remains, while the remaining 47 or 27.65 per cent contained parasites together with host pupal remains, the latter were invariably dead and shriveled. In a number of the grains parasite larvae were seen feeding on these host pupae.

It seems probable that where parasite eggs are laid on mature host larvae in the absence of preliminary paralyzation, the host larva may pupate in spite of the parasitization, the young parasite larva being able to eat into the pupa while its chitinous covering is still soft, finally destroying it and usually pupating, lying partly enclosed in the pupal remains. That this does take place at times was shown experimentally by using host larvae dissected from grain and placing parasite eggs on them just prior to pupation.

The Egg Stage

Immediately after deposition the contents of the egg are homogeneous, but as development progresses an oval, greenish zone of dense protoplasmic material can be seen in the central region of the egg (fig. 19).

With the progress of incubation, the general outline of the developing larva can be distinguished and it is seen no longer to occupy the entire egg; a small area at the anterior and posterior poles, as well

as an elongate zone along the concave or dorsal side of the egg being quite clear and transparent in contrast with the general grayish green color of the rest of the egg (fig. 20).

The chorion in these three clear regions then shrivels to a varying degree, thus decreasing the total length of the egg. The egg at its widest point still remains approximately the same, being entirely occupied by the head of the developing larva. The egg decreases from an average length of .509 mm. at deposition to an average of .478 mm. just prior to eclosion.

A few hours preceding emergence the fully developed larva can be vaguely seen through the chorion of the egg. Segmentation is faintly discernible and the larva can be seen twisting and turning within the egg. The chitinous mandibles can be seen and with these the larva tears a small hole in the end of the egg. This usually takes some little time and is generally made at one side of the egg near the cephalic pole. Sometimes, however, the larva eats its way out directly through the shriveled egg tip. Through the first small aperture made by the mandibles, the rounded, tubular area surrounding the mouthparts is forced out and the larva then proceeds to exert pressure until the chorion mechanically tears sufficiently to permit the larva's escape. The shriveled egg shells persist and are frequently found attached to the host larval remains and not infrequently attached to the integument of mature parasite larvae dissected from wheat grains.

The incubation period varied from 31 to 35 hours at a temperature of from 75° F to 77° F.

THE LARVAL STAGES

The outstanding larval morphological characters have been discussed earlier.

The larva on hatching is very active and crawls around for a short period before feeding, this period being as long as two hours in the case of eggs hatching on host larvae in petri dishes. Under these conditions, too, it seems to have limited ability to find the host; larvae hatching from eggs a few millimeters away from the host larva, frequently crawl off in the opposite direction and eventually die of starvation.

During this preliminary active period, the young larva destroyed all other eggs and parasite larvae with which it came in contact. The larva then settled down and ate a hole through the integument of the host larva, through the mouthparts and the rounded, elevated area

surrounding them, becoming all the while more or less buried in the host. It then began to feed by sucking out the liquid contents of the host.

Prior to feeding, the head is the most conspicuous part of the larva, being wider than any of the body segments. The alimentary canal can be seen as a narrow greenish colored central zone visible down to the base of segment ten.

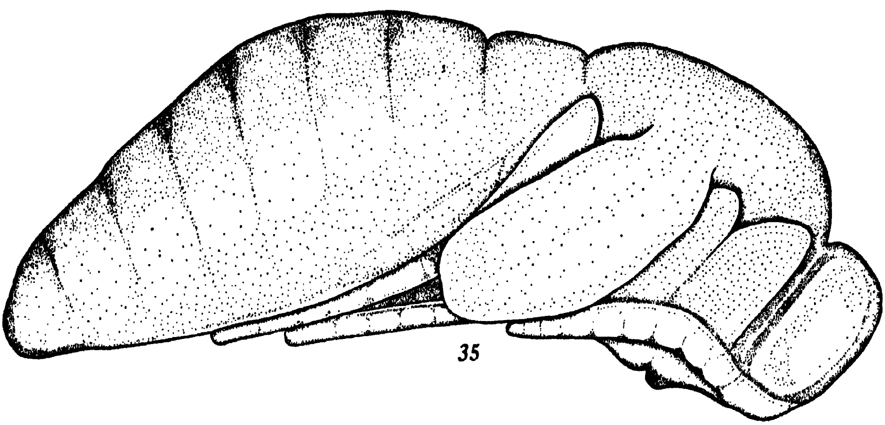
A common median ventral salivary gland is present which divides into two branches in the first segment within the base of the tentorium, one branch passing along each side of the alimentary canal. Soon after beginning to feed, the alimentary canal and the body segments begin to increase rapidly in size, the width of the head remaining the same until just before passing to the second stage, when the head is visible as a tiny structure, neither as wide nor as deep as the body segments, which at their broadest point are about twice the width of the head, and so greatly distended that it is difficult to distinguish the segmentation; the alimentary canal now occupies about two-thirds of the total width of the body.

The larva then moults, temporarily ceasing to feed but not necessarily changing its position, the skin splitting anteriorly and being slowly worked back along the body segments. The cast skin is very delicate and difficult to distinguish.

The second-stage larva may begin to feed upon the host before the cast skin has completely passed off of the posterior segments; indeed, it frequently remains as a fine pad on the ventral surface of the larva. The second-stage larva is more grayish green in general color and is now arched in outline, as opposed to the straight first-stage larva. There has been a considerable increase in the width of the head but the larva is broadest in the median abdominal segments sloping toward both ends, and the head is in much closer alignment with the rest of the body. The segments are very convex in outline and the larva is rather flaccid, indicating the extensive provision for increase of size in this stage. The integument is no longer produced into a tubular area surrounding the mouthparts.

With the intake of food the larva of this stage increases rapidly in size, and becomes more arched, its length finally being about twice that of the mature first-stage larva. During this stage the alimentary canal begins to be surrounded by fat body.

The larva then moults in a manner similar to stage I, the cast skins of both stages I and II occasionally being found adhering to the ventral surface of the third stage.



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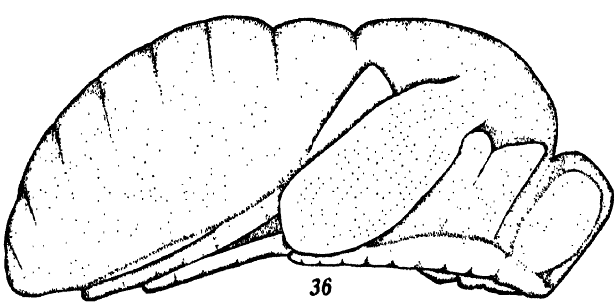

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Fig. 35. Female pupa. × 80.
Fig. 36. Male pupa. × 80.

Except for an increase in the width of the head and in the total length, the third-stage larva is very similar to stage II, being slightly more arched in outline and darker in color.

With the moulting of the third skin the larva enters on the fourth and final larval stage, an increase in the width of the head again being evident. The main features of this stage have been described under Morphology. It is more arched than in the previous stages, and varies from pale to dark gray in color. Sometimes the host larval remains turn black before the larva reaches maturity and the intake of these darker contents into the alimentary canal of the parasite larva tends to give an even darker color.

The narrow oesophagus passes down to the mouth in the ventral surface of the head and then back to the fore-intestine, which widens out to the mid-intestine, a huge globular sac occupying the greater part of the mature larva and more or less hidden by the dense layer of fat body surrounding it. On dissection the salivary glands are found to be very powerfully developed, passing backwards along each side and terminating just beyond the end of the mid-intestine, then passing forward to form a single fine duct which passes into the mouth ventrally (fig. 27).

In all the larval stages there is considerable variation in the feeding habits. Frequently the larva does not move from the original feeding position between moults and it may remain in the one position during the greater part of the larval period. On the other hand, it may change the feeding position frequently. Often the maturing larva becomes very restless and changes its feeding position many times during the last few hours before it leaves the host remains, which have by this time generally been reduced to a flaccid, shapeless mass.

Throughout larval life no waste matter is voided, all this being stored up in the mid-intestine until after the parasite larva has left the host; the hind-intestine is represented by a fine tube leading from the mid-intestine to the anus, there being at this time no opening between the hind- and mid-intestine.

Several times, maturing parasite larvae on being touched, have been observed to void clear drops of liquid from the anus, so that the anal aperture is evidently present at least during the late larval stages and certainly sometime before the opening between the mid- and the hind-intestine.

Length of the larval period.—The time required to pass through the larval stage at from 75° F to 77° F varied from 3.5 to 4.5 days, with an average of 3.75 days.

Time spent in the various larval stages.—Parasite larvae were kept under observation on exposed host larvae throughout their entire life and the times at which moults occurred were in a number of cases accurately checked at a temperature of from 75° F to 77° F. Two such cases are quoted below:

	Stage I	Stage II	Stage III	Stage IV up to time of leaving host	Total larval life
	hours	*hours*	*hours*	*hours*	*hours*
Larva number 1	29	27	20	20	96
Larva number 2	29	27.5	17.5	23	97

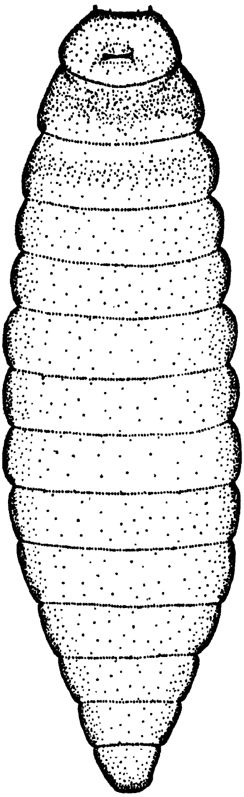
Amount of growth in the various larval stages.—A series of measurements of these larvae taken before and after each moult gave the following results:

		Width of head	Length of larva	Width of body at widest point
Larva No. 1	Stage I at hatching	.132 mm.	.409 mm.	.128 mm.
	Stage I on maturing	.132 mm.	.630 mm.	.221 mm.
	Stage II on maturing	.204 mm.	1.123 mm.	.425 mm.
	Stage III on maturing	.289 mm.	1.700 mm.	.579 mm.
	Stage IV on maturing	.374 mm.	2.350 mm.	.800 mm.
Larva No. 2	Stage I at hatching	.132 mm.	.409 mm.	.128 mm.
	Stage I on maturing	.132 mm.	.596 mm.	.187 mm.
	Stage II on maturing	.196 mm.	.902 mm.	.392 mm.
	Stage III on maturing	.272 mm.	1.5 mm.	.477 mm.
	Stage IV on maturing	.374 mm.	2.4 mm.	.766 mm.

The lengths of the mature larvae in this table are below the average but the figures nevertheless give a very fair idea of the proportional development in the various stages.

Influence of food deficiency.—It was frequently noticed that a certain number of minute individuals of both sexes appeared in the cultures, whose life-cycles were frequently much longer than life-cycles of individuals of normal size.

Investigation showed that these minute adults were the progeny hatched from eggs deposited on small host larvae, the diminutive size of the parasite being the result of an inadequate food supply.



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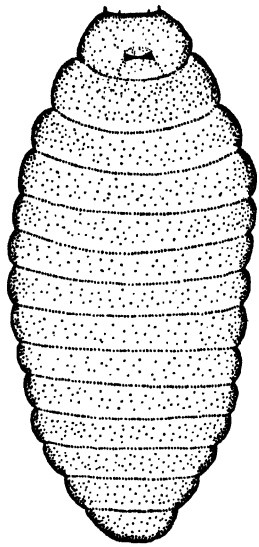

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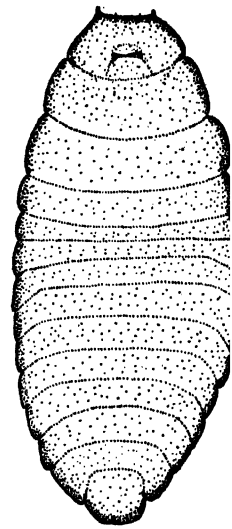

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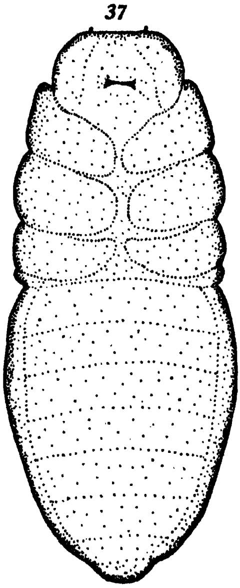

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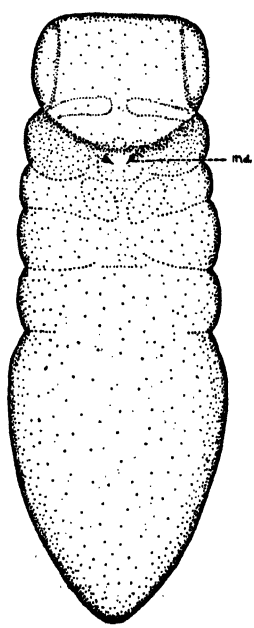

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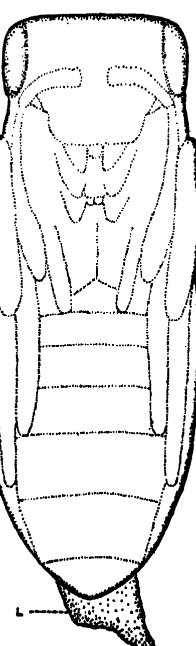

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(For explanation of figures see bottom of page 349)

Normally the parasite larva appears to ration the food supply throughout its life if the original host larva is small, and is thus able to complete its life-cycle in the normal way.

In the case of parasites reared on exposed larvae in the petri dishes, the host food supply sometimes became exhausted or unsuitable for the parasite larvae as early as the close of the third larval stage. Nevertheless, such larvae moulted, passed through the fourth stage with an absence of food, and finally emerged as adults. As it had no food during the fourth larval stage, it apparently drew upon the stored up fat body and was thus able to complete its metabolic processes; the time required to do this being very much longer than was required to complete the cycle where a normal food supply was available. This period was longer mainly because of a greatly extended pre-pupal period, which was as long as seven days at a temperature of from 75° F to 77° F, the resulting adult always being smaller than the average size.

Pre-pupal Stage

After maturing, the parasite larva crawls around actively for some hours, resting immobile for varying periods. Within the grain its range of movement is limited to the hole previously eaten out within the grain by the host larva. Sometimes this is not extensive and the parasite is forced to go through its subsequent changes lying partly on the host remains, though it does appear to try to get as far away from these as possible.

Some hours after the food supply has been left behind, the passage between the mid- and hind-intestine opens and the larva begins to void considerable quantities of brownish black, semi-liquid waste matter. As it does so, it gradually becomes paler in color and also shorter and less active. Finally it comes to lie on its back with the anterior and posterior segments conspicuously arched. In this position it voids the remainder of the waste matter and becomes quite white and immobile, having passed into the pre-pupal condition.

Changes from larval to pupal stage. × 55.
Fig. 37. Mature larva, ventral view.
Fig. 38. Mature larva passing into prepupal stage.
Fig. 39. Mature larva passing into prepupal stage.
Fig. 40. Prepupa.
Fig. 41. Head of pupa protruding from the larval skin; *md,* mandible of larva.
Fig. 42. Pupa: *L,* remains of larval skin.

The larval segmentation becomes indistinct and the pre-pupa becomes differentiated into two regions, an anterior narrower region, and a posterior oval portion which corresponds to the body of the pupa. Under the microscope the general outline of the pupa can now be seen within the skin of the pre-pupa, the last larval segments being unoccupied. The larval skin splits anteriorly and the head of the pupa projects. The pupa now exhibits slight movement and the larval mandibles can be seen passing down over the posterior segments as the larval skin is slowly worked back until it comes to lie as a tiny shriveled mass attached to the last segment of the pupa (figs. 37–42).

The time elapsing between the larva's leaving the host and its pupating at a temperature of from 75° F to 77° F varied from 1.5 days to 3 days, with an average of 2.5 days.

No cocoon is constructed.

THE PUPAL STAGE

Immediately after emerging from the pre-pupal stage, the pupa is white in color, but the position of the eyes and of various appendages can be distinguished, though they are very closely fused to the body surface. Within a few hours the pupa turns a very pale amber color and the appendages stand out more clearly.

The pupa slowly becomes more deeply pigmented, the eyes, ocelli, and the tips of the mandibles become quite black, while the thorax is still dark brown with the abdomen a much paler shade. Pigmentation progresses steadily until about 24 hours preceding emergence; the rate of pigmentation during this latter period is intensified, the pupa becoming a deep black and assuming the appearance of the adult.

EMERGENCE OF THE ADULT

Finally the pupa emerges within the grain. It eats its way out by cutting an irregular circular hole in the grain with its strong toothed mandibles. The head projects first through the hole and the parasite endeavors to crawl out. Sometimes it finds the hole it has eaten out is not sufficiently large whereupon it retreats into the grain and proceeds to bit off further pieces of the grain surface. After its emergence from the grain the antennae are often still covered with the thin sheath of the pupal stage and these are removed with the aid of the front feet.

The length of the pupal stage at from 75° F to 77°F varied from 5 days to 6.5 days, the pupal period for males being from 12 to 24 hours shorter than for females.

Length of Life-Cycle of the Parasite

The average length of the life-cycle of 214 individuals at a temperature of from 75° F to 77°F was 13.25 days with a minimum of 12 days and a maximum of 16 days. All the individuals emerging on the twelfth day were males, the shorter life-cycle in the male being mainly accounted for by the shorter pupal period.

In an individual with a life-cycle of 14 days the various stages were as follows:

Egg stage	1.5 days
Larval stage	4.0 days
Pre-pupal stage	2.5 days
Pupal stage	6.0 days
Total	14.0 days

With a decrease in temperature the life-cycle becomes correspondingly increased. A large jar of corn containing both host and parasite was placed in a room at 48° F on September 9, 1930, and was kept there for 132 days. The jar was then transferred to a temperature of 76° F. On inspection ten days later it was found that considerable numbers of parasites had emerged and later, host adults commenced to emerge. These parasites were probably in various stages of development at the time they were subjected to the lower temperature, so that the minimum life-cycle was greater than 132 days. The subjection of infested grain to this lower temperature provided a convenient method of keeping stocks of both the host and parasite available for long periods.

Life-Cycle of Host

The average life-cycle of 141 Angoumois grain moths at a temperature of from 75° F to 77° F was 46.68 days, with a minimum of 33 days, and a maximum of 70 days.

The average life-cycle of the parasite was over three times as rapid as that of the host at similar temperatures.

SUMMARY

Habrocytus cerealellae (Ashm.), which belongs to the hymenopterous superfamily *Chalcidoidea*, family *Pteromalidae*, and the subfamily *Pteromalinae*, was originally described as *Catolaccus cerealellae* by Ashmead in 1902.

The adult female parasitizes the larvae of the Angoumois grain moth, *Sitotroga cerealella* (Olivier), within infested grain.

Biological and morphological studies of the parasite have been carried out under laboratory conditions at Berkeley, California.

It was found that the parasite would oviposit on host larvae dissected from the grain and in this way it was possible to watch the development of the parasite throughout its entire life-cycle.

The length of life of adults varies considerably with varying conditions. They readily feed on sweetened solutions, a fact which adds to their length of life.

Females live longer than males under all conditions. At a temperature of from 42° F to 46° F some females lived more than 60 days.

Parthenogenetic reproduction occurs.

The total of the progeny of four fertilized females was 1014, of which 26.13 per cent were males and 73.87 per cent females.

Mating may occur within an hour after emergence and lasts from five to eight seconds; only one sexual contact occurs between the same pair.

There is a pre-oviposition period of 24 hours.

Three hundred and twenty-seven, 324, and 270 adults respectively were reared from eggs deposited by individual fertilized females.

The female pierces the infested grain with her ovipositor and frequently paralyzes the host larva before ovipositing on it; it may feed on the liquid which exudes through the wound.

The eggs are laid singly but superparasitism is quite common, as many as 16 eggs having been found on a single host larva within the grain and as many as 32 on exposed larvae.

Only one adult usually emerges, the first larva to hatch generally destroying the remaining eggs and larvae.

In several instances two parasites were reared from single host larvae.

Freshly hatched parasite larvae will feed on mature parasite larvae and one individual was experimentally brought through its entire life-cycle feeding only in this manner.

The period of oviposition varied from twelve to twenty-five days.

Four larval stages were distinguished; there was a well marked pre-pupal period.

At a temperature of from 75° F to 77° F the incubation period varied from 31 to 35 hours, the larval period varied from 3.5 to 4.5 days, the pre-pupal period varied from 1.5 to 3 days, and the pupal period varied from 5 to 6.5 days.

The average life-cycle of 214 individuals at a temperature of from 75° F to 77° F was 13.25 days with a minimum of 12 days and a maximum of 16 days; the life-cycle of the male being slightly less than that of the female.

At the same temperature the average life-cycle of 141 host individuals was 46.68 days, with a minimum of 33 days, and a maximum of 70 days.

LITERATURE CITED

ASHMEAD, W. H.

1902*a*. A new *Catolaccus* on *Sitotroga cerealella* (Olivier). Psyche, 9:345.

1902*b*. Classification of the chalcid flies, or the superfamily Chalcidoidea. Mem. Carnegie Mus., 1:225–532, 9 pls.

GIRAULT, A. A.

1917. The North American species of *Habrocytus* (Chalcid-flies). Canadian Entom., 49(5):178–182.

IMMS, A. D.

1918. Observations on the insect parasites of some *Coccidae*. Quart. Jour. Micr. Sci., 63:293–374.

1929. Some methods of technique applicable to entomology. Entom. Res., Bull. 20(2):165–171.

KINGSBURY, B. F., and JOHANNSEN, O. A.

1927. Histological technique (John Wiley & Sons, Inc., New York), pp. vii + 142, 16 figs. in text.

KURDJUMOV, N.

1913. Notes on Peteromalidae (Hymenoptera, Chalcidoidea). Rev. Russe d'Ent., 13:1–24, 2 pls.

PARKER, H. L.

1924. Recherches sur les formes post-embryonnaires des Chalcidiens. Soc. Entom. France, Ann., 93:261–379, 39 pls.

RIMSKY-KORSAKOV, M. N.

1914. Chalcids of the genus *Isosoma* injurious to grain crops in Russia. Memoirs of Bureau of Entom., Sci. Com. of Central Board of Land Administration and Agriculture, 10(11):84 pp., 50 figs., 3 pls.

THOMSON, C. G.

1878. Hym. Skand, 5:

URBAHNS, T. D.

1916. Life history of *Habrocytus medicaginis* Gahan., a recently described parasite of the chalcis fly in alfalfa seed. Jour. Agr. Resr., 7(4): 147–153, 1 pl.

VIERECK, H. L.

1916. The Hymenoptera or wasp-like insects of Connecticut. Guide to the insects of Connecticut, Bul. 22, Conn. State Geol. and Nat. Hist. Surv., pp. 824, 10 pls., 15 figs.

VOUKASSOVITCH, P.

1927. La Lutte pour la possession de l'hote chez les larves de chalcides ectoparasites solitaires. Bull. Biol. France-Belg. 61(3):315–325, 2 figs.

CONTRIBUTION TOWARD A REVISION OF THE AMERICAN SPECIES OF AMITERMES SILVESTRI

BY

S. F. LIGHT

In two recent papers I have described eight new American species of the genus *Amitermes* Silvestri, four from California (1930*a*) and four from western Mexico (1930*b*). These made a total of twenty species recorded from the Americas, nineteen in the type subgenus. Ten new species are described in the present paper while two others are reduced to synonomy, leaving a total of twenty-eight American species of *Amitermes* Silvestri as listed below.

Since the previous papers I have spent several months in and near the Coachella Valley, the narrow northern end of the extension of the Colorado Desert into southeastern California, in connection with the program of the Termite Investigations Committee. Here, within an area not more than twenty miles in diameter, are to be found seven of the eight very distinct species of this genus described in my paper on the California species of *Amitermes* (1930*a*) and much important information and material has been accumulated.

Through the kindness of Professor Alfred E. Emerson, of the University of Chicago, I have recently had the privilege of studying a small but important collection made by F. M. Gaige in the Fort Davis quadrangle in Texas, chiefly at Phantom Lake, during July 1916. The presence of several nest series, including alates, makes these collections especially important. Professor Emerson has further sent me for study paratype and cotype material of several South American species.

In addition to these collections, Doctor T. E. Snyder, of the United States Bureau of Entomology, has kindly allowed me to examine certain collections made subsequent to the publication of Bulletin 108 (Banks and Snyder 1920) and also some of the materials upon which were based the descriptions and distribution records given there.

A recent trip into southern Nevada for the Termite Investigations Committee made possible collections which have extended the known range of several species and produced the first physogastric queen (*A. coachellae* Light) taken in North America, as well as the hitherto unknown alates of that species (Light 1931). Collections of alates by Mr. R. W. Burgess, of the United States Department of Agriculture, at Coachella, Mr. L. F. Strehlke, in Palm Springs, and Mr. C. T. Lady, near Coachella, have produced the alates of two other species, *A. minimus* n. sp. and *A. emersoni* Light respectively, and two collections made by Mr. W. L. Bennington, of Calexico, added a hitherto unknown alate described below as *A. magnoculus* n. sp. as well as very interesting information as to time of swarming. A number of alates very recently received through the kindness of Professor W. B. Herms and collected by D. F. Macpherson at Beaumont represent still another new species, *A. fuscus*. Finally, the American Museum of Natural History has kindly sent me for study what seems to be a cotype or paratype of *A. wheeleri* Desneux which aided in establishing the identity of that species, and Dr. H. Schmitz, S. J., Curator of the Museum Wasmannianum, in which Padre Wasmann's collections are deposited, has kindly sent me two paratype soldiers of *A. foreli* for study. I have had at hand, therefore, authentic material of all the previously described American species.

The study of the California species in the field and in laboratory cultures has given new information as to their life-cycles, behavior, and distribution, and a study of the new California and Nevada material and the collections received from Doctors Emerson and Snyder and from the American Museum has cleared up several taxonomic tangles and made possible the description of several hitherto unknown alates and ten new species. It has seemed worth while to publish this information, incomplete as it is, in the hope of encouraging further study of these extremely interesting termites. The rich finds both in western Mexico and southeastern California indicate that careful collecting in our southwestern border states, particularly in Texas, Arizona, and New Mexico, will bring to light numerous new and interesting species as well as important information regarding the distribution and habits of known species.

Types have been sent to the U. S. National Museum and paratypes and cotypes are in the collections of Professor A. E. Emerson, of Professor F. Silvestri, of the California Academy of Science, and in my own collection.

The genus *Amitermes* was established by Silvestri (1901) in his preliminary paper on termites and termitophiles of South America and the name was so used by Wasmann (1903). Silvestri retained this spelling in the earlier, systematic portion of his full report (1903) but changed it to *Hamitermes* in the later, biological portion of the same paper (1903) and the latter spelling was used by Holmgren (1912) and others. I follow Banks (1920) and Emerson (1925) in retaining the original spelling of the genus.

The genus was considered by Holmgren (1912) to include six subgenera. Of these, but two, the type subgenus *Amitermes* and *Synhamitermes* Holmgren, have been reported from the Americas, the latter with but a single species, *S. brevicorniger* Silvestri from Chile. The other American species (see list below) have heretofore been included in the type subgenus. Decisions as to generic delimitation must await the results of the careful generic revision and studies of type material which Professor Emerson has been prosecuting for some years. Certainly the species of the *tubiformans* group, previously included in *Amitermes* s. str., differ sufficiently in morphology and size of both soldier and alate, as well as in habits, from the other members of that subgenus (as now used) to warrant considering them a separate subgenus, if not a separate genus. I have separated them, therefore, as a new subgenus of *Amitermes* Silvestri, which I have named *Gnathamitermes* from the remarkable development of the mandibles of the soldier caste which characterizes the species of the subgenus. A diagnosis of the new subgenus is found on page 390.

Until the publication of Bulletin 108 (Banks and Snyder 1920) but two North American species of *Amitermes* were known, *A. tubiformans* Buckley and *A. wheeleri* Desneux, the alate of the latter being unknown. Banks described four species as new, *A. arizonensis, A. californicus, A. confusus,* and *A. perplexus,* the last two being based on alates alone. He described also the supposed alates of the first two new species and of *A. tubiformans* Buckley.

Termites require special methods of preservation and study. They should be preserved in alcohol and studied in that medium under a compound microscope, preferably one of the high power, binocular dissecting microscopes with triple nose piece allowing for a considerable range of magnification and used with good artificial surface illumination. Measurements are made by means of an ocular micrometer. Attempts to identify American species of *Amitermes* by means of Banks' keys and descriptions early revealed discrepancies and lacks

which indicate that he was not well equipped for such studies. This, together with the ill-advised association of alates with soldiers when not taken together, has led to great confusion. As will be seen, two of his new specific names fall into synonomy and the three alates described with soldiers are each shown to belong to other species than the soldier with which they are described. This is peculiarly unfortunate since it renders unavailable at present much of the excellent information as to biology and distribution furnished by Snyder in his portion of Bulletin 108. It is to be hoped that Dr. Snyder will make this information available in connection with the new specific names and systematic distinctions.

I have long felt the importance of an attempt to work out specific characters of the workers of the species of this and other genera of termites in order to make possible workable keys to the species on the basis of worker characters. To this end a considerable study was made of the workers of the seven local species with generally unsatisfactory results. A few species are readily identified from the workers and it may be that a long, painstaking investigation might result in the formulation of satisfactory characters for distinguishing the remaining species, but at present such differentiation is not feasible and either the soldiers or reproductives, or both, must be depended upon for differentiation of the species.

In the list of American species of *Amitermes*, which follows, the species of *Amitermes* s. str. have again been arranged in more or less distinct groups of seemingly related species. Such grouping is entirely tentative and subject to change as new species are found and the alates, now unknown for many species, are discovered and studied. The present groupings will be seen to differ considerably from those given in my two former papers, notably in that three new groups are erected, the *medius* group for *A. medius* Banks, the *excellens* group for *A. excellens* Silvestri, and the *cryptodon* group for *A. cryptodon* Light; while the *wheeleri* group disappears and the *californicus* group is now designated the *amifer* group. The placing of *A. amifer* with *A. wheeleri* Desneux (= *A. californicus* Banks) is based on similarity between the alates, and the removal of *A. excellens* from that group on differences between the alates.

A LIST OF THE AMERICAN SPECIES OF THE GENUS *Amitermes* SILVESTRI

Subgenus *Synhamitermes* Holmgren

1. *Amitermes brevicorniger* Silvestri, Chile. Alate unknown.

Subgenus *Amitermes* s. str. Holmgren

The *medius* Group

2. *A. medius* Banks 1918, Central America.

The *amifer* Group

3. *A. amifer* Silvestri, Brazil and Argentina.
4. *A. wheeleri* Desneux, southeastern California, southern Nevada, Arizona, Texas (to extreme southeastern tip), western Mexico (at least as far south as Colima, Col.).
   (= *A. californicus* Banks and Snyder 1920, Light 1930*a* and *b*).
5. *A. foreli* Wasmann, Colombia. Alate unknown.

The *emersoni* Group

6. *A. beaumonti* Banks 1918, Central America.
7. *A. coachellae* Light 1930, southeastern California, southern Nevada, and southern Arizona.
8. *A. emersoni* Light 1930, southeastern California.
9. *A. ensifer* Light 1930, Colima, western Mexico. Alate unknown.
10. *A. minimus* new species, southeastern California, southern Nevada, Arizona, and Texas (to extreme southeastern tip).
11. *A. parvulus* new species, Texas (San Antonio), southern Arizona (?).
12. *A. silvestrianus* Light, southeastern California (Coachella Valley).

The *snyderi* Group

13. *A. snyderi* Light, southeastern California. Alate unknown.

The *excellens* Group

14. *A. excellens* Silvestri 1923, Guiana.

The *cryptodon* Group

15. *A. cryptodon* Light, Colima, western Mexico. Alate unknown.

Species based on alates and not placed by group—

16. *A. pallidus* new species, southern Arizona. Soldier unknown.
17. *A. parvipunctus* new species, Texas. Soldier unknown.
18. *A. spadix* new species, Texas. Soldier unknown.

Subgenus *Gnathamitermes* new subgenus

19. *A. acrognathus* new species, Texas.
20. *A. acutus* new species, southeastern California, southern Nevada, Arizona. Alate unknown.
21. *A. confusus* Banks 1920, Arizona and Texas. Soldier unknown.
22. *A. fuscus* new species, southeastern California. Soldier unknown.
23. *A. grandis* Light 1930, western Mexico. Alate unknown.
24. *A. infumatus* new species, western Mexico, southeastern California. Alate unknown.
25. *A. magnoculus* new species, southeastern California. Soldier unknown.
26. *A. nigriceps* Light 1930, western Mexico. Alate unknown.
27. *A. perplexus* Banks 1920, southeastern California, Arizona, and Texas.
28. *A. tubiformans* Buckley 1863, Arizona and Texas. Alate unknown.

Both alates and soldiers are known for twelve of these twenty-eight species, alates alone for six, and soldiers only for ten. The need of more complete collections, particularly of nest series containing alates is therefore sadly obvious.

SYSTEMATIC DISCUSSION

Terms and Methods

I have not attempted complete descriptions but have sought to limit myself to characters of known taxonomic significance. Careful comparative studies of the fontanel and fontanel area, the clypeus, the labrum, the labium and maxillae, the gulamentum, the nota, the legs, etc., would be of great value.

In general the terms used have the same significance as those used in my paper on the *Amitermes* of California (1930*a*). The value here designated as the mandible curvature index is the mandible curvature index II of the 1930 papers. A new index, *right tooth index,* arrived at by dividing the distance from the base of the right mandible to the front of the tooth by the length of that mandible, puts tooth level into comparable figures. *Head height index* derived by dividing maximum head height by head (capsule) length seeks to express relative height of the head. The difficulty of determining head height with exactitude makes for considerable error in this value. The *postclypeal index* used in descriptions of certain alates is the result of dividing length of postclypeus by breadth and seeks to replace the indefinite terms "long" and "short" by definitely comparable values. The dimensions concerned here are so small as to make for a very considerable probable error, hence small differences in this index should not be considered of importance.

All figures in text, both of alates and soldiers, are at the same magnification—approximately twenty-five diameters.

THE *MEDIUS* GROUP

This monotypic group is separated largely because of the strikingly different characters of the alate.

Alates moderately large; brown to dark brown in color; about 12 mm. long with the wings; head about 1.3 mm. wide through the eyes; pronotum about 1.10 mm. wide; eyes very large (fig. A), hardly separated from ventral margin.

Soldiers large; head about 1.5 mm. wide; high, vaulted with strongly convex lower margin; fontanel large, postclypeus strongly bilobed; mandibles long, strongly curved; teeth prominent, cone-shaped, near middle of mandible.

Amitermes medius Banks

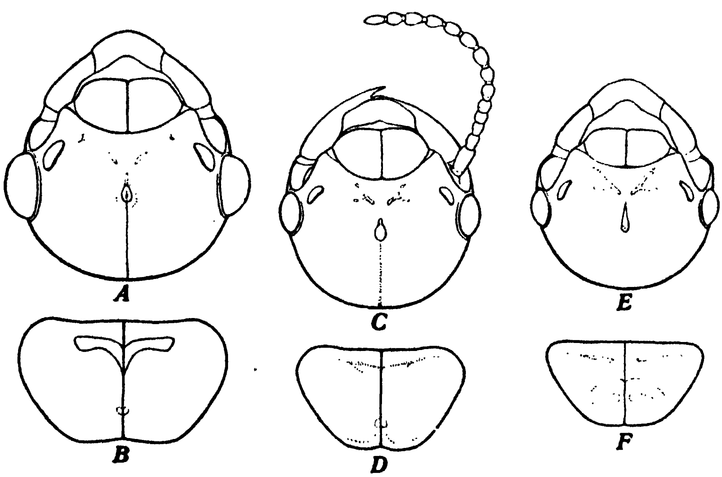
Figures A and B

Amitermes medius Banks 1920, Snyder 1924, Light 1930*c*.

Brief Redescription of Alate (from Panama)—

Head and pronotum brown; postclypeus light brown; labrum, antennae, palpi, legs, and abdominal tergites pale brownish yellow; abdominal tergites smoky brown.

Head (fig. A) broad, short, ovate, much narrowed in front; head capsule much broader than long, broadest at anterior margin of eyes, converging strongly behind the eyes; head high in front of middle of eye, sloping posteriorly; posterior margin straight.



Figures A–F. Alates of *Amitermes medium* Banks, *A. amifer* Silvestri, and A. *wheeleri* Desneux. All figures *ca.* × 25.

Figs. A and B. Head and pronotum respectively of alate of *A. medius* Banks from Panama.

Figs. C and D. Head and pronotum respectively of alate of *A. amifer* Silvestri.

Figs. E and F. Head and pronotum respectively of alate of *A. wheeleri* Desneux.

Fontanel (fig. A) large, white, conspicuous; located in middle of head, just behind level of ocelli, oval in shape, continued as short, narrow line in front; muscle markings faint, narrow, oblique.

Postclypeus (fig. A) more than twice as wide as long, flatly vaulted, strongly convex behind.

Eye (fig. A) very large, round, separated from ventral margin by less than one-quarter its diameter, from dorsal margin by about one-quarter its diameter, and from posterior margin by a little more than its diameter.

Ocelli large, broadly oval, short diameter about two-thirds of long diameter, separated from eye by less than one-half of short diameter.

Antennae of sixteen segments; third shortest.

Pronotum (fig. B) with arms of Y marking distinct, dull yellow, nearly transverse; anterior margin nearly straight; posterior margin emarginate; antero-lateral corners broadly rounded; sides convex, strongly convergent.

Measurements in Millimeters of *Amitermes medius* Banks from Panama

Length with wings	12.00
Forewing length	10.00
Head length over all	1.41
Head capsule length	.90
Head width through eyes	1.26
Eye, long diameter	.41
Ocellus, long diameter	.20
Ocellus, short diameter	.15
Postclypeus length	.28
Postclypeus width	.52
Postclypeal index	.54
Pronotum length	.60
Pronotum width	1.08

THE *AMIFER* GROUP

In this group I have placed three species, *A. amifer* Silvestri, the type species of the genus, *A. foreli* Wasmann, and *A. wheeleri* Desneux which I show to be the *A. californicus* of Banks and Snyder (1920) and Light (1930*a* and *b*).

The alates (unknown for *A. foreli*) are characterized by small size, about 10 mm. long with the wings and with a head width of less than 1.15 mm.; by the general brown color of head, body, and wings; by relatively short antennae of fourteen or fifteen segments; by a pronotum narrower than the head capsule and longer than half its own breadth, with strongly converging, nearly straight sides; and by a long postclypeus.

The soldiers are characterized by strongly curved mandibles; by cone-shaped, inwardly directed teeth; by a high, domed head, set high behind; and by a gula distinctly narrowed behind.

Amitermes amifer Silvestri

Figures C, D, G, and H

Amitermes amifer Silvestri 1901, 1903 (systematic portion); Emerson 1925.
Hamitermes hamifer Silvestri 1903 (biological portion); Holmgren 1912.

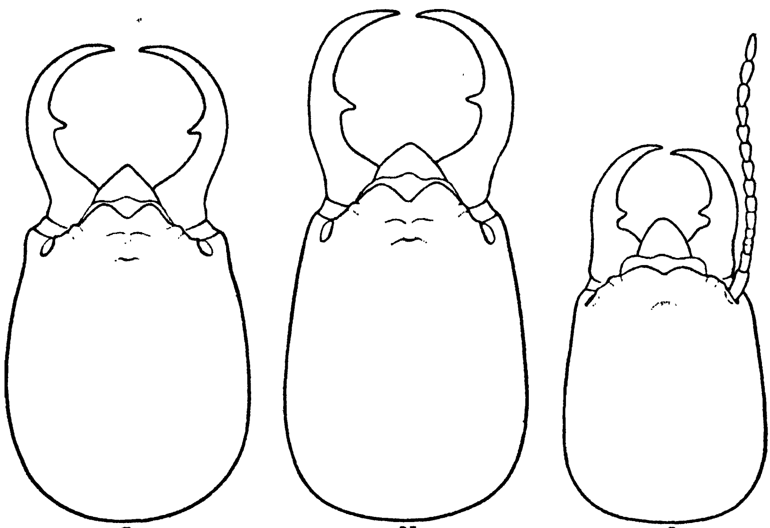
This, the type species of the genus, was well described by Silvestri (1903). Since the original description was in Italian, however, and in order to bring out certain characters which have proved themselves of importance in the speciation of the genus, I present here a brief

description of the alate and soldier based on cotype and metatype material available through the kindness of Professor Emerson.

Alate.—Generally brown in color; head russet brown with reddish tone; pronotum light rusty brown; abdominal tergites brown; sternites extremely pale brown; postclypeus, labrum, antennae, palpi and legs light yellow; wings pale brown.

Head capsule (fig. C) broadest in front of eyes, somewhat convergent behind; posterior margin broad, weakly convex; head flat above, low behind, highest at level of ocelli, sloping posteriorly.

Fontanel (fig. C) elongated, white; muscle markings (fig. C) small.



G H I

Figures G–I. Soldiers of *Amitermes amifer* Silvestri and *A. wheeleri* Desneux. All figures *ca.* × 25.

Fig. G. Head of cotype soldier of *A. amifer* Silvestri from Brazil.

Fig. H. Head of metatype soldier of *A. amifer* Silvestri from Brazil.

Fig. I. Head of small type soldier of *A. wheeleri* Desneux. This type was described by Banks (1920) as *A. wheeleri* while the large type with shorter, heavier teeth and mandibles was described as *A. californicus* Banks.

Postclypeus (fig. C) long and narrow, postclypeal index 0.59; strongly concave.

Ocelli about half as long as diameter of eye, oval; somewhat broader than one-half their length; separated from eyes by about their short diameter and from the margin of the head capsule by somewhat less than once and a half their length.

Eyes small, circular, separated from ventral margin of head by a little more than half their diameter, from dorsal surface by a little less than their diameter, and from the posterior margin by a little less than twice their diameter.

Antennae of fourteen segments as in figure C.

Pronotum (fig. D) considerably longer than one-half its width; anterior margin hardly concave; antero-lateral corners broadly rounded; sides strongly convergent, straight; posterior margin biconvex.

Measurements in Millimeters of Cotype Alate of *Amitermes amifer* Silvestri from Brazil

Length with wings	10.00
Forewing length	7.50
Head length over all	1.14
Head capsule length	.74
Head width through eyes	.96
Eye, long diameter	.21
Ocellus, long diameter	.12
Ocellus, short diameter	.09
Postclypeus length	.26
Postclypeus width	.44
Pronotum length	.48
Pronotum width	.81
Postclypeal index	.59

Descriptions and measurements based on cotype (male) alate collected and determined by Silvestri from Cuyabo, Matto Grosso, Brazil, July 9, 1900.

Soldier.—Head, bases of mandibles, antennae, and pronotum yellow; distal two-thirds of mandibles red; mandibular articulations and fontanel reddish.

Head (figs. G and H) subrectangular, elongated, converging slightly from behind middle; sides faintly convex; posterior margin nearly straight; head high, domed; head index about 0.75; head contraction index about 0.85.

Fontanel large, postclypeus deeply grooved and bilobed.

Antennae slender, delicate, of thirteen or fourteen segments; third narrowest, fourth shortest; terminal segment longest save first.

Mandibles long, very slender, strongly convex; strongly incurved from the middle; head-mandible index about 0.60 mm.; teeth at about middle, small, slender, conical, directed inward and somewhat basally.

Gula unusual in shape, broadest at extreme anterior end, sharply narrowed, and then gradually narrowed until near posterior end; a faint indication of a bulge at anterior one-third.

Descriptions and measurements based on a cotype soldier determined and collected by Silvestri in Coxipo (Çuyabo), Brazil, July 9, 1900, and numerous metatype soldiers from Urucum de Corumba, Brazil, collected by K. P. Schmidt, compared and determined by Emerson.

MEASUREMENTS OF METATYPE AND COTYPE SOLDIERS OF
Amitermes amifer SILVESTRI

	A Metatype	B Cotype
Head length	1.56	1.44
Head width, maximum	1.14	1.11
Head width, minimum	.93	.81
Mandible length	.93	.81
Gular length	1.13	1.04
Gular width, maximum	.32	.32
Gular width, minimum	.23	.20
Pronotum width	.78	.72
Head index	.73	.77
Head contraction index	.82	.73
Head-mandible index	.60	.56
Gular contraction index	.72	.63
Mandible curvature, minimum	.32	.29
Mandible curvature index	.34	....

Variation.—There is considerable variation to be noted in the soldiers. The cotype soldier is smaller (figs. G and H), with relatively narrower head, as the measurements will show, and less strongly convergent sides. The mandibles are somewhat longer in proportion and the tooth is longer, more slender, and more basally directed. There seems, however, to be no reason to doubt their conspecificity.

Amitermes foreli Wasmann

Plate 10 and figure UU (p. 407)

Dentitermes foreli Wasmann 1902*a*.
Hamitermes foreli Holmgren 1912.

This species, apparently the first species of the genus collected in the Americas, was taken by Forel in 1896 at Barranguilla, Colombia. Wasmann's description was not published, however, until 1902 (1903), two years after Silvestri's paper (1901) in which he described *A. amifer* and *A. brevicorniger.* The redescription of the soldier of this interesting species, the alate of which is unknown, has been made possible through the kindness of Dr. H. Schmitz., S. J., of the Museum Wasmannianum, who sent me for study two beautifully mounted soldiers of the type collection. The characters of mandibles and teeth place it clearly in the *amifer* group, very near to *A. amifer,* from which it differs in its much larger size, the weaker curvature of its mandibles, etc.

Soldier.—Large, head about 1.75 mm. long and 1.40 mm. wide; body chalky white in dried specimens; head pale chalky yellow, mandibles shading from yellow at the bases to brownish red in distal third; head with very long, slender, widely scattered, reddish hairs; frons

with shorter, more numerous reddish hairs, particularly in the zone just behind the fontanel.

Head (pl. 10, figs. 1 and 2; fig. UU) very much uplifted behind, sloping forward from near occiput; head broad ovate in dorsal view; head index about 0.80; sides somewhat convex, strongly convergent; head contraction index about 0.75.

Fontanel small, aperture about .02 mm. in diameter, rimmed with white, located at base of face of vertical fontanel protuberance; a pronounced groove running from fontanel across clypeus to which it gives a distinctly bilobed appearance (fig. UU).

Mandibles (pl. 10, fig. 1; fig. UU) long, smooth, relatively slender, strongly curved beyond the teeth; teeth at about middle, inwardly and slightly posteriorly directed, long, slender, sharp, spine-like.

Gula bent upward behind, due to uplifted head; broadest near front, narrowed behind.

Antennae slender, of eleven (+ ?) segments; distal segments elongated; eleventh segment (fig. VV) as long as first, nearly as long as second, third, and fourth together.

Measurements in Millimeters, and Indices, of Two Paratype Soldiers of *Amitermes foreli* (Wasmann)

Head length	1.80	1.72
Head, maximum width	1.50	1.38
Head, minimum width	1.08	1.05
Mandible, length	1.02	1.02
Minimum mandible curvature	0.216	0.21
Pronotum, width	0.84	.....
Head index	0.83	0.79
Head contraction index	0.72	0.76
Head-mandible index	0.57	0.59

Amitermes wheeleri (Desneux)

Figures E, F, and I

Termes wheeleri Desneux 1905.
Amitermes wheeleri Banks and Snyder 1920 (ex parte).
Amitermes californicus Banks and Snyder 1920 (soldiers) Light 1930*a*, *b*.
Amitermes arizonensis Banks and Snyder 1920 (alates).
Not *Amitermes wheeleri* Banks and Snyder 1920, Brownsville and San Antonio, Texas, nor Snyder 1925, nor Light 1930*a* and 1930*b* (all of which = *A. minimus* n. sp.).

A careful examination of the material allocated to *A. wheeleri* Desneux by Banks has shown it to include two species, *A. wheeleri* Desneux (= *A. californicus* Banks) and *A. minimus* n. sp., both small and with basally located teeth in the soldier caste. An attempt to locate Desneux's type was unsuccessful. It was reported by Banks as questionably in the Paris Museum (*sic*). As was to have been expected, since M. Desneux was Belgian, it is not in the Museum

d'Histoire Naturelle. Dr. Wheeler, the collector, has no type material, but a paratype was reported by Banks (1920) to be in the American Museum of Natural History in New York and Dr. Lutz kindly sent me this material for study. It is clearly conspecific with the *A. californicus* of Banks and labeled "From a vial marked '*Termes wheeleri* Desneux ex typé, Belton, Texas.' Determined by Banks and Snyder." This last statement seemed to cloud the issue but Dr. Snyder tells me that his records indicate that paratype material from the American Museum was used in their studies. The internal evidence also points to its being a paratype. For example, the use of the older generic name *Termes* far antedates the work of Banks and Snyder; also Belton is the type locality for *A. wheeleri* Desneux, and Banks and Snyder had no termite material from that locality, and indeed no other collections save those of Wheeler reported by Desneux are known to have been made there. We would be justified, therefore, in considering this an authentic paratype since but a single collection of this species was made by Wheeler. Fortunately, however, Desneux's description, while lacking in some points, is sufficiently clear as regards the most diagnostic structure, the mandible, to show that Desneux could have had no other species of American *Amitermes* than the one described by Banks as *Amitermes californicus*. Desneux says, "Mandibules assez courtes, à peu près de la longuer de la moitiè de la tête . . . . fortement arquées. . . . .". In all other known American species, if not in all species of the type subgenus the head-mandible index is much more than 0.50 (usually more than 0.70) and in *A. minimus* n. sp. it is about 0.70. There can be little doubt, therefore, that Desneux's *Termes wheeleri* is the *A. californicus* of Banks. Banks' descriptions and illustrations are based on the slender-mandibled type of soldier (fig. G) which I have mentioned (1930*b*) as occurring with the more typical soldiers of this species.

Banks described alates of this species, of which he says "Although not taken with soldiers it is practically certain that they belong to this species." The examples of the confusion resulting from the several such decisions on Banks' part will, it is hoped, discourage future workers from such assumptions.

A collection taken by F. M. Gaige at Phantom Lake, Fort Davis, Texas, contains both soldiers and alates, the latter very distinct from those described by Banks. While there is always a possibility of error in such collections, it seems necessary to consider these alates, taken with soldiers, to be the real alates of *A. wheeleri*. These seem to be

the same as the alate described by Banks as that of *A. arizonensis,* and hence that name also becomes a synonym of *A. wheeleri* Desneux, since Banks designated the winged adult as type. He seemed not to have distinguished between these alates and those described by me later in this paper as *A. parvulus* and hence his distribution data cannot be used. It is barely possible, of course, that his type is the same as my *A. parvulus,* in which case we would be forced to use the name *A. arizonensis* for that species, a situation much to be regretted because of its long association with soldiers of an entirely different type.

The alates described by Banks as belonging to *A. californicus* have been taken swarming several times in Sabino Canyon but never with soldiers and hence must be considered a new species. They are very small and very light in general color and are described later in the paper (p. 385) as *A. pallidus* n. sp.

A brief description of the alate of *A. wheeleri* Desneux (Gaige No. 112) follows.

Head dark brown; postclypeus, labrum, and palpi light yellow; pronotum pale, rusty. Head as in figure E; broadest in front of eyes, converging behind; posterior margin weakly convex. Fontanel narrow, slit-like. Muscle markings not conspicuous; oblique markings long and narrow; transverse marking short. Eye medium in size; truncated antero-dorsally; separated from ventral margin by somewhat less than half its long diameter and from dorsal margin by about half its long diameter. Ocelli very shortly oval, relatively large, about as long as half the long diameter of eye; separated from eyes by nearly their short diameter. Postclypeus swollen, not much more than twice as wide as long. Pronotum as in figure F.

Material examined is from five localities in Texas: Cotulla, Kingsville, Uvalde, Chalk Bluff, and Laguna (Uvalde County), and Brownsville, all collected by Dr. T. E. Snyder.

Measurements of Alate of *Amitermes wheeleri* Desneux from Phantom Lake, Texas

Forewing length	9.50
Head length over all	1.23
Head capsule length	.84
Head width through eyes	1.02
Eye, long diameter	.23
Ocellus, long diameter	.12
Ocellus, short diameter	.09
Postclypeus length	.25
Postclypeus width	.49
Pronotum length	.48
Pronotum width	.84
Postclypeal index	.51

MEASUREMENTS OF SOLDIER OF *A. wheeleri* DESNEUX
ASSOCIATED WITH ALATE DESCRIBED ABOVE

Head length	1.38
Head width, maximum	1.14
Head width, minimum	.99
Mandible length	.64
Gular length	.64
Gular width, maximum	.38
Gular width, minimum	.23
Pronotum width	.72
Head index	.83
Head contraction index	.87
Head-mandible index	.46
Gular contraction index	.61
Inner mandible length	.49
Mandible curvature, minimum	.08
Mandible curvature index	.13

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIERS OF *A. wheeleri* DESNEUX OF THE SMALL TYPE (FIG. 1) FROM FOUR LOCALITIES IN TEXAS

	Chalk Bluff, Uvalde Co.	Laguna, Uvalde Co.	Kingsville	Brownsville
Head length	1.17	1.23	1.35	1.29
Head width, maximum	.96	.93	1.05	.99
Head width, minimum	.78	.81	.81	.84
Mandible length	.67	.62	.64	.70
Gular length	.58	.70	.67	.64
Gular width, maximum	.29	.31	.32	.28
Gular width, minimum	.23	.23	.23	.20
Head index	.82	.76	.78	.77
Head contraction index	.81	.87	.77	.85
Head-mandible index	.57	.50	.47	.54
Gular contraction index	.79	.74	.72	.71
Inner mandible length	....	.48	.49	.49
Minimum mandible curvature	....	.10	.10	0.094
Mandible curvature index	....	.16	.16	.13

Distribution.—This species has a remarkable range, from Los Angeles County, California, south to Colima, Colima, Mexico, and east across the continent to Brownsville, Texas, in the extreme southeastern tip of Texas.

THE *EMERSONI* GROUP

This, the largest group of American species of *Amitermes* s. str., includes as here constituted six species as follows: *A. beaumonti* Banks, *A. coachellae* Light, *A. emersoni* Light, *A. ensifer* Light, *A. minimus* n. sp., *A. parvulus* n. sp., and *A. silvestrianus* Light. Alates are known for *A. coachellae, A. emersoni, A. parvulus, A. minimus,* and doubtfully for *A. beaumonti.* The known alates agree in being

small (8.5–10 mm. long with wings) and dark, but it is impossible to state the characters of the alates of the group until they are more fully known. The soldiers are characterized by small, distally sharp, more or less basally directed teeth, located at or beyond the middle save in *A. coachellae*, *A. parvulus*, and *A. minimus* where they are basally located.

The group may prove to be a heterogeneous one when the alates are more completely known. *A. parvulus*, *A. minimus*, and *A. coachellae* with basally located, shelf-like teeth in the soldier caste seem distinct as regards characters of the soldier caste but the alates are not greatly different from those of *A. emersoni.* *A. silvestrianus* with soldier mandibles similar to those of *A. emersoni* varies in having a brown rather than black alate.

Here probably belong some or all of the three new species, *A. pallidus*, *A. parvipunctus*, and *A. spadix*, described later in the paper from alates alone.

Amitermes beaumonti Banks

Amitermes beaumonti Banks 1918; ?Snyder 1925; Snyder 1926.
Amitermes beaumonti Light 1930*b*, pl. 17, fig. 6.

This species was described by Banks (1918) from soldiers collected by Beaumont in Panama. Banks mentions having alates, separately collected, which he believes belong to this species. These alates are described by Snyder (1925) and from their size seem to fit the soldiers and the group. It will be necessary, however, to await the finding of nest series or careful comparison with late nymphs taken with soldiers before we can be certain of the identity of these alates.

It has seemed worth while to supplement Banks' brief description and give more extensive measurements.

DESCRIPTION OF SOLDIER OF *Amitermes beaumonti* BANKS FROM BARRO-COLORADO ISLAND (KIRBY)

Head and basal half of mandibles very pale yellow; distal half of mandibles light red; mandibular articulations reddish; antennae yellow; otherwise whitish.

Head broad ovate, sides strongly convex; postero-lateral corners rounding very broadly into faintly convex posterior margin; head high, domed, sloping in all directions from center; hairs long, reddish, numerous.

Mandibles strongly and evenly curved in distal half; proximal half nearly straight; tooth at or slightly beyond distal one-third, large, sharp, posteriorly directed, somewhat shelf-like.

Antennae somewhat elongated, once and one-half as long as mandibles; of fourteen segments; third and fourth very small.

Labrum blunt. Gula somewhat narrow behind. Gular contraction index about 0.67.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF A SOLDIER OF *Amitermes beaumonti* BANKS FROM BARRO-COLORADO ISLAND, PANAMA

Head length	1.32
Head width, maximum	1.08
Head width, minimum	.81
Mandible length	.81
Gular length	.83
Gular width, maximum	.48
Gular width, minimum	.32
Pronotum width	.66
Head index	0.82
Head contraction index	0.75
Head-mandible index	0.73
Mandible curvature, minimum	0.20
Mandible curvature index	0.25
Gular contraction index	0.67

Amitermes coachellae Light

Figures J and K

Amitermes coachellae Light 1930*a*.

DESCRIPTION

Alate.—Generally smoky black of various tones contrasting sharply with the brilliant white of unpigmented areas; head capsule and pronotum black; basal leg segments, ventral thoracic sclerites abdominal tergites, lateral areas on sternites, and posterior portions of meso- and metanota somewhat lighter; other pigmented areas, including wing membrane, still lighter smoky black.

Head shaped as in figure J, widest in front of eyes; sides receding strongly behind; posterior margin weakly convex.

Fontanel conspicuous white; short oval with pointed ends, tending to be infuscated posteriorly; preceded by a very short, narrow white line. Muscle markings as in figure J; narrow and inconspicuous.

Postclypeus pale smoky in color with one to several lighter spots on either side, not strongly swollen; short, about half as long as wide, postclypeal index about 0.50.

Eyes round, separated from upper and lower margins of head by more than half their diameter, from front margin by fully their diameter, and from hind margin by about once and a half their diameter.

Ocelli very small, short oval, their long diameter less than half diameter of eye; separated from eye by at least their long diameter.

Antennae (fig. J) of 15–16 segments; third rudimentary, fourth and fifth subequal.

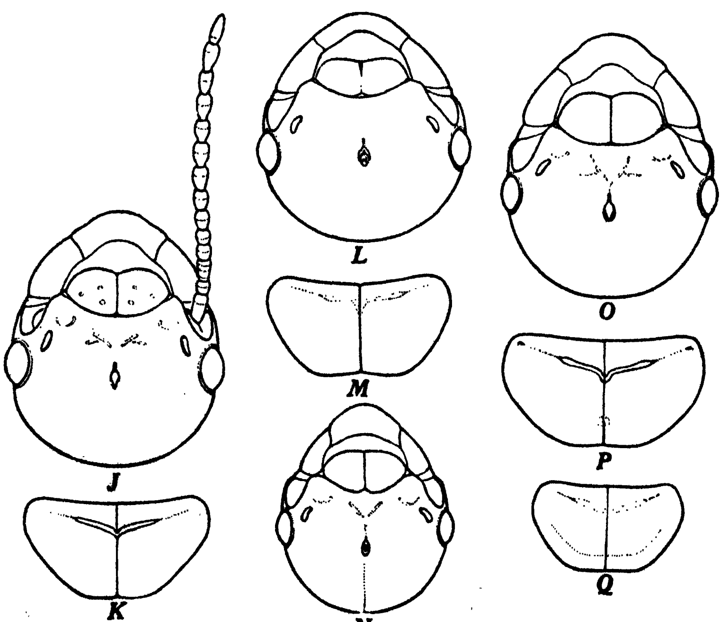
Pronotum (fig. K) with entire, nearly straight or faintly concave anterior margin; antero-lateral corner broadly rounded; sides some-

what convex, strongly receding; posterior margin narrow, straight; surface with a conspicuous, dull yellowish, very flatly V-shaped marking.

Anterior margin of wings dark; radius and radius sector light; a dark line lying along the posterior margin of the radius sector.

Measurements in Millimeters of an Alate of *Amitermes coachellae* Light from Boulder City, Nevada

Length with wings	10.00
Forewing length	8.00
Head length over all	1.32
Head capsule length	.84
Head width through eyes	1.08
Eye, long diameter	.22
Ocellus, long diameter	.09
Ocellus, short diameter	.06
Postclypeus length	.26
Postclypeus width	.49
Postclypeal index	.53
Pronotum length	.48
Pronotum width	.93



Figures J–Q. Alates of species of the *emersoni* group. All figures *ca.* × 25.

Fig. J. Head of *A. coachellae* Light.
Fig. K. Pronotum of same.
Fig. L. Head of *A. emersoni* Light.
Fig. M. Pronotum of same.
Fig. N. Head of *A. minimus* Light.
Fig. O. Head of *A. silvestrianus* Light.
Fig. P. Pronotum of same.
Fig. Q. Pronotum of *A. minimus* Light.

Physogastric queen.—Agrees with the alates save, strangely enough, in its color, being much lighter and brown instead of black, and the pigment of the lateral and ventral sclerites is in tiny discontinuous granules or spots. This lighter color might be explained on the basis of premature emergence were it not that very incompletely pigmented alates from the same colony show an entirely different color, a pale smoky black without any traces of brown.

MEASUREMENTS IN MILLIMETERS OF A PHYSOGASTRIC QUEEN OF *Amitermes coachellae* LIGHT FROM BOULDER CITY, NEVADA

Head length over all	1.32
Head capsule length	.78
Head with through eyes	1.02
Eye, long diameter	.20
Ocellus, long diameter	.07
Ocellus, short diameter	.07
Postclypeus length	.26
Postclypeus width	.48
Postclypeal index	.54
Pronotum length	.42
Pronotum width	.93
Abdomen width	4.40
Abdomen length	13.00

Soldier.—Head, pronotum, antennae, labrum, and palpi yellow; head very light in mid-dorsal area, dark in front; mandibles reddish yellow basally, smoky red distally; other parts whitish.

Thorax about half as wide as head; abdomen long, spindle-shaped, not greatly swollen, but little wider than head.

Head subrectangular; sides weakly convex, converging slightly in anterior third; postero-lateral corners squarely rounded; posterior margin weakly convex; head index about 0.80; head contraction index about 0.95; head relatively low; head height index about 0.55 mm.; frons not especially declivitous, bulging in center above fontanel; hairs reddish, widely scattered save in zone behind fontanel protuberance.

Mandibles relatively long, relatively slender, bent slightly at level of teeth, incurved in outer distal one-fourth, very sharp distally; teeth shelf-like, projecting slightly, succeeded proximally by a deep, narrow, triangular notch.

Antennae of fifteen segments, third very small.

Labrum longer than broad, tip rounded, somewhat uplifted. Gula scarcely narrowed behind, gular contraction index about 0.90 mm.

Distribution and biology.—This species was very briefly described in my paper on the California species of *Amitermes* (1930*a*) from three collections made by Castle and Williams in the upper Coachella Valley. Later I found it to be very abundant in certain definitely limited areas in the same region, especially in one particular wash near the type locality. *A. coachellae* was practically the only species

found in the wash which was very narrow and from six to twelve feet deep. It was present in and on the under surface of nearly every piece of partly buried wood in the wash while not a single colony was found at the surface level. It was found also on the bank of the San Gorgonio River at the same level and was the only *Amitermes* species found in the Whitewater River bed in Whitewater Canyon nearby. *Reticulitermes tibialis* is present in all these areas and while not in exactly the same spots, close association of the two species might seem to indicate similar ecological predelictions. Their moisture and temperature requirements are actually, however, very different, since during the warmer period of the fall when *R. tibialis* was rarely encountered, *A. coachellae* was abundant. After the first cold fall rain the reverse was true. *A. coachellae* was then not to be found, having retreated to warmer, less moist lower levels, and *R. tibialis* was very abundant, present in most pieces of surface wood.

The alate of *A. coachellae* was not known until on a recent trip to Boulder City townsite a nest was found containing a large colony with hundreds of alates and a physogastric queen (Light 1931). These made possible the identification of several alates of this species taken flying in Tucson, Arizona, by Professors Vorhies and Nichol about noon on February 20, 1929. A single alate was taken by me at about the same time but in a different part of the city. There had been a light rain the evening before.

The nest taken at Boulder City was found buried from six to fifteen inches under a broad, flat stone sunk two to three inches in the sand of a draw. The nest was of the same general structure and appearance as that found by Castle in the upper Coachella Valley (Light 1930*a*). The underside of the rock itself was covered with a considerable accumulation of black-lined chambers which were crowded with alates, late reproductive nymphs, a few younger nymphs, and very few workers. A few isolated chambers contained very young nymphs. One contained numerous eggs, several older nymphs, and numerous young nymphs.

Some eight inches under ground a more extensive nest structure was found, consisting of broad, horizontal chambers from about six to ten millimeters high, with smooth, black inner surfaces. These contained many workers, some alates, and reproductive nymphs of various stages.

The lowest nest, which was some fifteen inches under ground, contained no alates or reproductive nymphs, which seemed concentrated

nearer the surface. Workers were abundant and here for the first time in my experience of collecting *Amitermes* the soldiers were abundant. No soldiers were found just under the stone, and only one in the intermediate nest, but here every gallery was guarded by one or more of them. Near the center of this nest was a flat, low circular chamber, about two inches across, containing the physogastric queen, the first of the genus to be taken in this country. A single, very active dealate male taken in the same nest may have been the king.

The low percentage of soldiers in the foraging groups, from which collections of *Amitermes* are ordinarily taken, is known to every collector and had led to the impression that they represent a very low percentage of the population of a colony. This finding would indicate that they are present in a proportion more normal for termites, but concentrated largely in the vicinity of the royal cell. This raises the question as to the reasons which make their presence there of value to the colony. The only obvious hypothesis is that they are guarding the nest and particularly the royal pair from attack by ants or possibly other termites.

Amitermes emersoni Light

Figures L and M

Amitermes emersoni Light 1930*a* and *b*.

Since my recent description of this species, which was based on soldiers and workers, two collections of the previously unknown alates have been taken with soldiers, one by Mr. R. W. Burgess, of the United States Bureau of Entomology at Coachella, and the other by Mr. C. T. Lady, near Thermal, both in the Coachella Valley.

Description of the Alate of *Amitermes emersoni* Light

All chitinized portions shiny black save labrum, antennae, palpi, and abdominal sternites which are smoky black, the tarsi which are white, and the wings which are pale brown black. Head, legs, pronotum, other thoracic sclerites and abdominal sclerites with a thick coat of light yellowish hairs.

Head shaped as in figure L; sides receding strongly behind, rounding into strongly convex posterior margin.

Fontanel narrow oval but appearing as a tiny Y because of extensive infuscation of its posterior portion. No muscle markings visible. A small diamond-shaped white spot in the center between postclypeus and frons.

Postclypeus short, hardly swollen; postclypeal index about 0.51; posterior margin not markedly convex; anterior margin somewhat concave.

Eye small, inconspicuous because of deep black color of head, ringed with yellow, antero-posteriorly elongated; separated from both dorsal and ventral margin of the head by more than half its diameter, from the anterior margin of head capsule by a little more than its diameter and from the hind margin by about twice its diameter.

Occellus small, oval, its short diameter vertical; less than half as long as diameter of eye; separated from eye by about its own diameter.

Antennae of fifteen segments; third rudimentary; fourth and fifth subequal, smaller than sixth, together longer than second.

Pronotum (fig. M) considerably shorter than half its width; anterior margin broadly but very weakly concave; antero-lateral corners rounded; sides nearly straight, receding and rounding broadly into broadly and very shallowly concave posterior margin.

Costal margin of wings consisting of a yellow band along extreme distal edge bearing a close set line of hairs followed by a thick, opaque white vein (radius); radius sector opaque white save basally where infuscated, succeeded by a somewhat narrower dark smoky black line; other veins light yellow margined by narrow light smoky brown line; proximal portions of main veins and proximal branches of cubitus thicker and darker; median about twice as far from radius sector as from cubitus; one to several short, dark, incomplete, nearly vertical posterior branches from radius sector.

MEASUREMENTS OF AN ALATE OF *Amitermes emersoni* LIGHT FROM COACHELLA

Length with wings	12.00
Forewing length	9.50
Head length over all	1.26
Head capsule length	.78
Head width through eyes	1.08
Eye, long diameter	.20
Ocellus, long diameter	.10
Ocellus, short diameter	.09
Postclypeus length	.25
Postclypeus width	.49
Postclypeal index	.51
Pronotum length	.42
Pronotum width	.90

Nymph.—Alates taken in flight at Palm Springs had previously been tentatively identified as the alates of this species on the basis of fairly close agreement with late instar reproductive nymphs of *A. emersoni*. Similar nymphs of *A. silvestrianus* Light taken later showed these alates to be without doubt those of *A. silvestrianus*. Certain critical measurements of late instar reproductive nymphs of *A. emersoni* follow.

MEASUREMENTS IN MILLIMETERS OF LAST INSTAR REPRODUCTIVE NYMPH OF *A. emersoni* LIGHT FROM PALM SPRINGS

Head width	0.99
Head capsule length	1.08
Pronotum length	0.48
Pronotum width	0.90
Length of wing pads	3.24

Distribution and biology.—Although it is still known only from the Coachella Valley, my recent investigations in that region have shown this species to be one of the commonest termites in certain portions of that area. It is abundant, for example, in and along the dry bed of the Whitewater River from near Garnet down at least as far as Thermal, replacing in these lower reaches *A. coachellae* which was not found below 1200 feet. It would be extremely interesting to determine the boundaries of the specific ranges of these species and the factors limiting their local and geographical distributions.

As the intensely black color of the alate would lead one to expect, *A. emersoni* is a day flier. Mr. R. W. Burgess, who took them swarming in Coachella on January 31 and February 4, 1931, reports that

all specimens were taken in the morning. The earlier season flights were less abundant, the greatest flight being on February 4 when the air was full of the winged forms for most of the morning and well into the afternoon. Both these flights followed rains. 0.09 inches fell on January 30 and 0.44 inches on February 3. Those swarming on January 31 were emerging from the roots of dead Bermuda grass and there soldiers and workers were taken. Those swarming February 4 were emerging from a ball park and a fallow field, both of hard clay loam, ordinarily very hard and dry. The latter contained no vegetation above ground, but roots of dead Bermuda grass were present. They were swarming from numerous holes within a two-foot area.

Amitermes minimus n. sp.

Plate 9, figures 3, 4, and 7; figures N and Q

Amitermes wheeleri Banks and Snyder 1920 (*ex parte:* Brownsville and San Antonio, Texas).
Amitermes wheeleri Snyder 1925 (alates).
Amitermes wheeleri Light 1930*a* and *b*.

This is the most widespread and in certain localities the most abundant species of *Amitermes* in southeastern California. Three collections from Texas are before me, two from San Antonio (Gable) and one from Brownsville (Snyder). This gives the species a known range of some 1300 miles, practically spanning the continent. Records from the intervening area are extremely meager, there being but two records, near Las Vegas, Nevada (Light 1931) and near Tucson,

Arizona (Light 1930*a*). It may be expected to be common, however, in favorable localities through Arizona, New Mexico, Texas, and northern Mexico.

The species is characterized by its small size (hence the specific name), the head being less than 0.8 mm. wide in the worker caste, about the same width in the alate, and less than 0.9 mm. wide in the soldier caste, while the alate is only about 8.5 mm. long with the wings.

Snyder (1925) describes and figures alates taken flying at San Antonio on July 12 at 8:15 in the morning. I have numerous alates taken swarming on September 2 in a gnat trap at Coachella, California, by Mr. R. W. Burgess of the United States Bureau of Entomology. These agree very well with Snyder's description. It may be of interest to give measurements of a typical individual (dried) of my collection.

MEASUREMENTS IN MILLIMETERS OF AN ALATE OF *Amitermes minimus* SP. NOV. FROM COACHELLA

Length with wings	7.50
Forewing length	6.00
Head length over all	1.08
Head capsule length	.75
Head width, through eyes	.90
Eye, long diameter	.23
Ocellus, long diameter	.09
Ocellus, short diameter	.06
Postclypeus length	.22
Postclypeus width	.44
Postclypeal index	.50
Pronotum length	.48
Pronotum width	.78

Biology.—There is little to add to my previous discussion of the biology of this species (1930*a*) save that Snyder's report of serious damage done by *Amitermes wheeleri* Banks must be held in abeyance until we know which of the species grouped by Banks under that name was really involved.

While *A. minimus* n. sp. does not construct covered ways above the ground, it does build hard, crusty, often sand-covered galleries over the ground side or buried portion of wood which is being attacked, as do the other species of the subgenus. It seems more prone to attack upright pieces of wood including fence posts and poles than are the other *Amitermes* species of California and is the only species of the genus in that area, which penetrates the wood extensively and therefore the one most likely to be of economic significance.

Amitermes parvulus n. sp.

Figures Z, AA, and WW

Amitermes arizonensis Banks 1920 (alates in part).

Collection records.—A single alate, marked "*Amitermes* (*A*) *wheeleri* Desn.", locality unknown, presumably from Texas; three alates taken in July at lights in Sabino Canyon, near Tucson, Arizona (Hofer); a nest series with numerous alates and soldiers taken October 8, 1921, at San Antonio, Texas (G. H. Gable).

Alate.—Generally brown above and yellow below; antennae and postclypeus smoky yellow; labrum, tarsi, and distal end of tibiae yellow; abdominal sternites light brown; head, pronotum, and body with a heavy coat of long, whitish hairs.

Head (fig. Z) short, rounded behind the eyes. Fontanel very small, narrow oval, somewhat pointed behind; merged broadly in front with short, broad, preceding line. Muscle marking inconspicuous, oblique markings first visible about halfway between end of line preceding fontanel and front of head capsule.

Postclypeus as in figure Z. Eyes elongated antero-posterially; separated from lower margin of head by about half their short diameter, from dorsal margin of head by about half their long diameter or a little more, and from posterior margin by about twice their long diameter.

Ocelli large, about two-thirds as long as eyes; more than half as wide as long; near eyes, separated by less than their short diameter.

Pronotum (fig. AA) short; in dorsal view about half as long as broad; sides bent down; antero-lateral corners broadly rounded; sides convex, receding strongly into narrow straight posterior margin.

Wings pale brown, the line behind radius sector and the basal branches of the cubitus dark brown.

MEASUREMENTS OF ALATE OF *Amitermes parvulus* N. SP.

Head length over all	1.02
Head capsule length	.69
Head width, through eyes	.84
Eye, long diameter	.23
Ocellus, long diameter	.12
Ocellus, short diameter	.07
Postclypeus, length	.21
Postclypeus width	.38
Postclypeal index	.55
Pronotum length	.39
Pronotum width	.75

Soldier.—Small; head capsule (fig. WW) slightly more than 1 mm. in length and about 0.85 mm. wide, head index about 0.8; head rectangular with sides parallel or slightly convex, contraction index 1.0 or slightly less; head high, sides and posterior surface steep, nearly vertical, giving head box-like shape; postero-lateral corners very shortly rounded; posterior margin slightly convex.

Mandibles (fig. WW) heavy and short, head-mandible index less than 0.6; mandibles strongly curved in outer third.

Teeth (fig. WW) much as in *A minimus* n. sp. but because of shortened mandible, lying not far below middle of mandible.

Gula with nearly straight sides, gular contraction index about 0.95.

Measurements in Millimeters, and Indices, of Two Soldiers Each of *Amitermes parvulus* new species and *A. minimus* new species

	A. parvulus		*A. minimus*	
Head length	1.08	1.05	1.08	1.08
Head width, maximum	0.87	0.84	0.90	0.90
Head width, minimum	0.87	0.78	0.84	0.78
Mandible, length	0.61	0.60	0.78	0.78
Gula, length	0.55	0.55	......	0.61
Gula, maximum width	0.275	0.27	0.28	0.29
Gula, minimum width	0.26	0.255	0.19	0.19
Head index	0.80	0.80	0.83	0.83
Head contraction index	1.00	0.93	0.93	0.87
Head-mandible index	0.56	0.58	0.72	0.72
Gular contraction index	0.94	0.94	0.77	0.75
Minimum mandible curvature	0.0725	0.0725	0.116	0.087
Mandible curvature index	0.12	0.12	0.15	0.11

Systematic discussion.—As this paper was about to go to press the Gable collection was received through the kindness of Dr. Snyder. This included the hitherto unknown soldiers which place the species in the *emersoni* group as here constituted, near to *A. minimus,* from which it differs most importantly in the short broad mandibles, the box-like head of the soldier, and in the generally smaller size of the alate. This is the smallest known *Amitermes* alate. As pointed out above it seems to have been included by Banks with the alates here shown to belong to *A. wheeleri* as the alates of his *A. arizonensis.* Banks' description agrees with the alate of *A. wheeleri.* If, however, the type should prove to be the same as my *A. parvulus,* we would face the unfortunate necessity of using the name *A. arizonensis* for this species.

Amitermes silvestrianus Light

Plate 9, figures 1, 2, 8, 12, and 13; figures O and P

Amitermes silvestrianus Light 1930*a* and 1930*b*.

The alate of this species is here described for the first time and the soldier is briefly redescribed.

Alate.—Head capsule, pronotum, and other thoracic segments a more of less smoky dark brown; abdominal tergites lighter smoky brown black; abdominal sternites pale whitish in centers, pale smoky yellow brown laterally; antennae and postclypeus light smoky brown; palpi and legs very light brown; labrum paler.

Head (pl. 9, fig. 1; fig. O) broad; receding behind eyes and rounding very broadly into convex posterior border.

Fontanel oval, long, narrow, with somewhat pointed ends; small anterior V-shaped area white, conspicuous; remainder more or less infuscated and obscure but lighter than head. Muscle markings as in figure forming a double branched Y.

Postclypeus hardly twice as wide as long; hardly swollen; anterior margin straight or weakly biconvex.

Eyes rounded or slightly elongated dorso-ventrally; separated from upper and lower margins by more than one-half their diameter and from posterior margin by about twice their diameter.

Ocelli small, about half as long as diameter of eye; separated from eye by about their long diameter.

Antennae of fifteen segments; third smallest, fourth and fifth next smallest.

Pronotum (pl. 9, fig. 2; fig. P) considerably more than twice as long as broad; anterior margin straight; antero-lateral corners very broadly rounded; sides convex, strongly receding; posterior margin broadly and shallowly concave; transverse markings yellow, narrow but distinct, oblique.

Wings as in figures 12 and 13 of plate 9.

MEASUREMENTS IN MILLIMETERS OF AN ALATE OF *Amitermes silvestrianus* LIGHT FROM PALM SPRINGS

Length with wings	11.50
Forewing length	8.25
Head length over all	1.32
Head capsule length	.90
Head width, through eyes	1.08
Eye, long diameter	.23
Ocellus, long diameter	.09
Ocellus, short diameter	.07
Postclypeus length	.26
Postclypeus width	.49
Postclypeal index	.53
Pronotum length	.54
Pronotum width	.99

MEASUREMENTS IN MILLIMETERS OF LAST INSTAR REPRODUCTIVE NYMPH OF *A. silvestrianus* LIGHT

Head width	.96
Head capsule length	.90
Pronotum length	.48
Pronotum width	.96
Wingpad length	2.04

Soldier.—Generally light; head, antennae, and basal third of mandible yellow; distal two-thirds of mandibles light smoky red; otherwise whitish.

Head very broad oval to subrectangular; sides and posterior margin broadly but weakly convex; sides somewhat convergent in anterior one-third; head index about 0.82; head contraction index about 0.95;

head highest near posterior end, sides rising to center; fontanel area conspicuous owing to numerous reddish hairs; projection not prominent, weakly arcuate; hairing sparse in general.

Antennae long, longer than head capsule; of fifteen segments; third and fourth incompletely separated.

Mandibles relatively long, wide but flat, incurved from about middle; tooth somewhat beyond middle, sharp, prominent, basally directed; tooth shelf-like making mandible broad, sometimes very broad in distal one-third or more.

Biology and distribution.—This species was based on the soldiers of a single colony collected by Castle in the dry bed of the Whitewater River near Garnet in the Coachella Valley of southeastern California. Later during my stay in the Coachella Valley I encountered it only in two localities, both high, side washes dropping off into the bed of the Whitewater River, one just below Palm Springs (a part of the Palm Canyon Wash) and the other on the east side of the river some two miles south of Cathedral City. In this particular area about three hundred yards long and fifty yards wide the species was extremely abundant, present in every piece of favorably located wood. Near the river end of this wash a few colonies of *A. emersoni* were encountered and on the next lower level no more than five feet lower and but a few feet away, *A. emersoni* was present everywhere and not a single colony of *A. silvestrianus* was found. This would seem to indicate a very narrow ecological niche.

Like the other desert species of *Amitermes*, save those of the subgenus *Gnathamitermes*, *A. silvestrianus* confines its attacks to wood in or on the ground and its workings to the ground side or to cavities eaten into the softer wood. It builds thick, brownish, outer encrusting galleries often from one-half to an inch in thickness. Similar frass is present within their workings in wood which they occasionally penetrate deeply.

The alates here described were not taken with soldiers but the agreement between them and last instar nymphs which were taken with soldiers is so exact, especially in the characters which separate the alates of this species from other *Amitermes* alates of the region, that there is no question in my mind as to this identification. The most striking differences between alates of the two species commonly found together is, of course, the very black color of *A. emersoni* in contrast to the brown of *A. silvestrianus*. This, of course, is lacking in the nymphs. Other differences are to be made out in the nymphs as well. Most striking of these are differences in head, pronotum, postclypeus, and wings. The head of *A. silvestrianus* is much broader in proportion

to the length of the head capsule. This is the most obvious difference between the nymphs of the two species. The wings of *A. emersoni* are considerably longer than those of *A. silvestrianus* and the same is true for the two nymphs available for comparison, as a comparison of the measurements of the two will show. The postclypeus of *A. emersoni* has a distinctly concave anterior margin in both alate and nymph whereas it is straight in both alate and nymph of *A. silvestrianus*. Finally the pronotum of alate and nymph of *A. silvestrianus* differs in its much more broadly rounded antero-lateral corners and strongly convex sides.

These alates were collected by Mr. L. F. Strehlke of Palm Springs. I give his interesting account of their capture.

These few specimens were gathered on August 3, two days after a very heavy rainfall during which an inch of rain fell in one hour. I was sleeping out of doors because of the great heat. My bed was a cot situated in a cement floored court between two buildings. When I awoke at about five o'clock in the morning I was greeted with the very interesting sight of thousands of insects flying to and fro three to six feet above the ground. The flight was so slow and sluggish that I had no difficulty in reaching up my hand from the cot on which I was lying to capture them at will. These I preserved and are the ones I am turning over to you. Just before sunrise these insects began to drop to the ground or pavement. After dropping they would make a few trials to fly at which they would succeed only after a fashion. They would soon abandon their attempts to fly and would crawl about aimlessly and then of a sudden drop their wings. The entire wing equipment would fall from the body at once. At this stage the insect would go about excitedly until it mated, which seemed almost immediately. The two would then crawl rapidly about, one following the other in such close formation as to have the appearance of one insect. They would run about nervously in no fixed direction but seemingly seeking shelter of any crack, fissure, or deep depression that might occur in the cement pavement. Shortly after sun-up, about thirty minutes as I remember it, I was unable to find a single, live insect. The only evidence remaining of their recent visitation was the countless thousands of tiny wings covering the cement pavement.

This habit of flying in the very early morning, and not necessarily during the day, immediately after rain may account for the rarity of such captures.

THE *SNYDERI* GROUP

Here I have tentatively segregated a species, *A. snyderi* Light, whose alate is not known and whose soldier is relatively large (head with mandibles about 2.50 mm. long) with heavy, bent mandibles, the teeth being located beyond the middle.

Amitermes snyderi Light

Amitermes snyderi Light 1930*a* and 1930*b*.

While no further collections of this species have been made it seems worth while to describe a late first-form nymph since these have been found very useful in the identification of alates in other species. The single late nymph available is evidently not in the last instar, which must be kept in mind in interpreting the description.

Abdomen swollen, black intestinal contents visible; wing pads reaching to third abdominal segment. Eyes small, about 0.15 mm. in diameter, incompletely pigmented.

Head strongly receding behind the eyes; posterior margin convex; postclypeus shorter than half its breadth, anterior margin convex.

Pronotum twice as broad as long, anterior border straight; anterolateral corners rounding broadly into convex, strongly receding sides; posterior margin broadly and shallowly concave.

Measurements in Millimeters of Reproductive Nymph of *Amitermes snyderi* Light

Length	5.58
Length of wing pads	1.86
Head length over all	1.16
Head length	0.58
Head width	0.97
Postclypeus length	0.23
Postclypeus width	0.49
Pronotum length	0.46
Pronotum width	0.72

THE *EXCELLENS* GROUP

This group as constituted consists of a single species, *A. excellens* Silvestri. It is characterized so far as the soldier is concerned by the slight curvature of the mandibles save near the tip and by the small cone-shaped tooth located near the base.

The alate is large, 12 mm. or more with wings, very dark, and with an extremely long postclypeus.

THE *CRYPTODON* GROUP

This monotypic group is erected to receive the very small species *A. cryptodon* Light (1930*b*). The alate is unknown. The soldier mandibles differ strongly from those of any other known species in that they are flat, weakly curved throughout with but little distal incurvature and in that the tooth is not sharp or projecting but shelf-like with a long distal and shorter proximal face.

UNPLACED ALATES OF *Amitermes* S. STR.

The collections kindly put at my disposal by Dr. Snyder contain a number of small *Amitermes* alates without soldiers, taken swarming in most cases. Some of these were studied by Banks (1920) who considered them, mistakenly, to represent the alates respectively of *A. arizonensis* Banks, *A. tubiformans* Buckley, and *A. californicus* Banks. Four different species are represented in these collections, three of which I have described as new species including the alates allocated by Banks to *A. tubiformans* and *A. californicus* and some of the alates placed in *A. arizonensis* by Banks.

An alphabetical list of these new species follows:

Amitermes pallidus n. sp.
Amitermes parvipunctus n. sp.
Amitermes spadix n. sp.

The only species of *Amitermes* s. str. of the United States for which the alate remains unknown is *A. snyderi* Light. As this is a large species, it seems unlikely that any of these small alates belong to it. This condition indicates the need for more careful and extensive collecting.

Brief descriptions of these three species follow with figures of head and pronota and measurements of single individuals. Differences in measured proportions of small structures such as postclypeus and pronotum should be used with caution until careful comparative studies are available.

Amitermes pallidus n. sp.

Figures R and S

Amitermes californicus Banks 1920 (alates).

Collection records.—Numerous collections, all taken by Hofer at lights in Sabino Canyon, Arizona, mostly during July but once each in June and August.

Alate.—Generally light; head light brown; pronotum, wing scales, meso- and metanota, and lateral thoracic sclerites light rusty brown; postclypeus, labrum, antennae, palpi, legs, ventral thoracic sclerites, and abdominal sternites yellow; abdominal tergites very pale yellow brown.

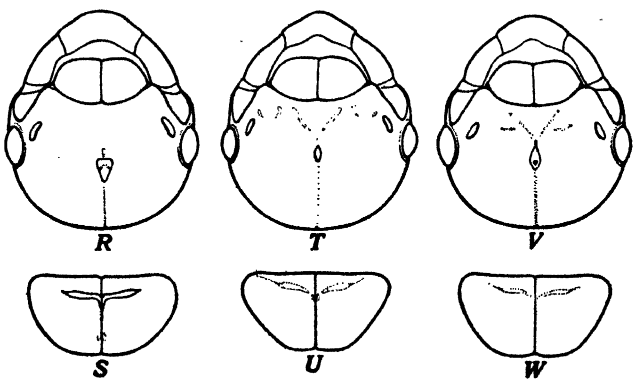
Small, only 9.5 mm. long with wings; head about 1. mm. wide. Head as in figure R, sides strongly receding, rounding broadly into convex posterior margin; broadest in front of eyes; head low, lowest behind, highest just in front of level of ocelli.

Fontanel large, white conspicuous, broad ovate to triangular; broad in front, more or less extensively infuscated behind; front marked by narrow, transverse, bracket-shaped white zone; preceded by a short, white or yellow line.

Muscle markings obscure; mid-longitudinal suture distinct behind. Postclypeus more than twice as broad as long; broadly and very shallowly concave anteriorly; somewhat swollen.

Eyes circular, flat; separated from dorsal and ventral margins of head by more than half their diameter and from posterior margin of head by about twice their diameter.

Ocellus short oval; about as long as half diameter of eye; near eye, separated from it by less than half its short diameter.



Figures R–W. Heads and pronota of new species of *Amitermes* s. str. based on alates only. All figures *ca.* × 25.

Fig. R. Head of *A. pallidus* Light.
Fig. S. Pronotum of same.
Fig. T. Head of *A. parvipunctus* Light.
Fig. U. Pronotum of same.
Fig. V. Head of *A. spadix* Light.
Fig. W. Pronotum of same.

Antennae somewhat elongated, of fifteen segments; third smallest. Pronotum (fig. S) small, narrower than head between the eyes, about twice as broad as long; anterior margin straight or sligthly concave; widest near front; antero-lateral corners very shortly rounded; sides convex, converging, rounding broadly into weakly biconvex posterior margin.

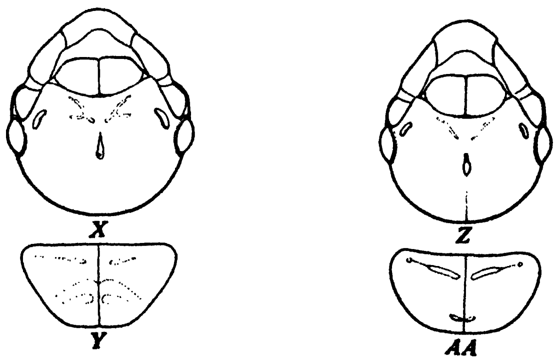
MEASUREMENTS IN MILLIMETERS OF ALATE OF
Amitermes pallidus N. SP.

Length with wings	9.50
Forewing length	7.00
Head length over all	1.20
Head capsule length	.74
Head width, through eyes	.99
Eye, long diameter	.23
Ocellus, long diameter	.12
Ocellus, short diameter	.09
Postclypeus length	.20
Postclypeus width	.46
Pronotum length	.42
Pronotum width	.72
Postclypeal index	.44

Variation.—The ocellus varies somewhat in size. When smaller it is nearly round and separated from the eye by nearly its short diameter. The fontanel varies decidedly in degree of infuscation, being sometimes entirely infuscated save anterior bracket which then with anterior line makes a shallow Y.

This alate is easily distinguished by the naked eye from all other alates of the genus known to me, by its very light color.

Systematic position.—This is the alate described by Banks (1920) as that of his *A. californicus* (here shown to be *A. wheeleri* Desneux).



Figures X–AA. Heads and pronota of alates of *A. wheeleri* Desneux and *A. parvulus* Light. Both *ca.* × 25.

Fig. X. Head of *A. wheeleri* Desneux.

Fig. Y. Pronotum of same.

Fig. Z. Head of *A. parvulus* Light.

Fig. AA. Pronotum of same.

He says, "Although not taken with soldiers, it is practically certain that they belong to this species." As pointed out under the description of *A. wheeleri* Desneux, the alates taken with soldiers of this species (Texas, Gaige, No. 112) and there described, differ in several points from the alates here described as *A. pallidus* n. sp. For example, the fontanel of the Texas alate is very narrow, the eyes are projecting and elongated, the pronotum with straight, strongly receding sides, and the wings more than 9 mm. long, while in *A. pallidus* the fontanel is broad, the eyes flat, the pronotum with strongly convex sides, less strongly receding, and the wings are about 7 mm. long. In other characters they are suggestively alike save that the Texas alates are darker. These alates are very common in Sabino Canyon as are the soldiers of *A. wheeleri* Desneux but so also are the alates ascribed to *A. arizonensis* Banks which seem to agree with those here described as *A. wheeleri,* and those of *A. parvulus* are also found. Intensive collecting in Sabino Canyon, therefore, should produce the unknown soldiers of *A. pallidus* n. sp. and *A. parvulus* n. sp.

Amitermes parvipunctus n. sp.

Figures T and U

Collection records.—Several alates taken in flight at Uvalde, Texas, on June 25, 1917, by D. C. Parman (Hopk. 15240, Hopk. 14096) and two alates whose locality is not known to me.

Alate.—Generally light brown; head darker; postclypeus, antennae, palpi and labrum, and abdominal sternites yellow brown.

Head (fig. T) broad, relatively high.

Fontanel very small; elongate, pointed at both ends, continuous in front with very short preceding line; muscle markings obscure. Postclypeus swollen, about half as long as wide.

Eyes somewhat elongated dorso-ventrally; separated from ventral margin of head by about half their short diameter, from dorsal margin by slightly more and from posterior margin by about twice their long diameter.

Ocelli very small, nearly round, in front of middle of eye; separated from eye by about their diameter.

Antennae of fifteen segments; third rudimentary; fourth and fifth much broader than long; sixth twice as broad as long; seventh to twelfth about as broad as long; thirteenth longer than broad; fourteenth about twice as long as broad; fifteenth longest, slender.

Pronotum (fig. U) with shortly rounded antero-lateral corners, straight, strongly receding sides, and broadly but shallowly emarginate posterior margin.

MEASUREMENTS OF TWO ALATES OF *A. parvipunctus* N. SP.

	A	B
Length with wings	....	9.50
Forewing length	8.00	7.50
Head length over all	1.14	1.14
Head capsule length	.72	.78
Head width, through eyes	.96	.96
Eye, long diameter	.23	.20
Ocellus, long diameter	.09	.12
Ocellus, short diameter	.06	.09
Postclypeus length	.26	.25
Postclypeus width	.44	.44
Postclypeal index	.59	.57
Pronotum length	.42	.42
Pronotum width	.78	.81

Amitermes spadix n. sp.

Figures V and W

Amitermes tubiformans Banks and Snyder 1920 (alates).

Collection records.—With soldiers and workers of *A. tubiformans* under cowchip near Uvalde, Texas, May 5, 1917 (Snyder).

Alate.—Generally dark brown; legs and abdominal sternites lighter brown; pronotum rusty; labrum and tibiae yellow.

Head (fig. V) with broad, only weakly convex posterior margin; sides not strongly receding behind the eyes; slightly contracted anteriorly; head capsule highest in front, sloping backward, low behind.

Fontanel narrow ovate; pointed at both ends; narrow in front; marked by a small subcircular infuscated spot behind; preceded by a very short, contiguous yellow spot with which are continuous the long, very narrow, oblique muscle markings which diverge and curve slightly outward, ending in spots near the anterior margin of the capsule; transverse markings less conspicuous, somewhat oblique.

Postclypeus swollen; infuscated; wider than twice its length.

Eyes elongated in a postero-dorsal—antero-ventral axis; separated from ventral margin of head by about half their short diameter, from dorsal margin by fully their short diameter, and from the posterior margin by slightly less than once and a half their long diameter.

Ocelli small, short and broad; about as long as one-half short diameter of eye; separated from eyes by about their own length.

Antennae robust, of fifteen segments; third rudimentary; fourth and fifth very short; sixth about as wide as long; seventh to twelfth somewhat longer, subequal; thirteenth somewhat longer; fourteenth twice as long as wide; fifteenth longest, narrow, pointed.

Pronotum (fig. W) about twice as wide as long; anterior margin uplifted in middle, otherwise straight; antero-lateral corners rounded; sides straight or weakly convex; receding strongly from in front of middle; rounding broadly into narrow, very faintly biconvex posterior margin.

MEASUREMENTS OF TWO ALATES OF *Amitermes spadix* N. SP.

Forewing length	7.50	8.00
Head length over all	1.14	1.14
Head capsule length	.75	.72
Head width through eyes	.99	.96
Eyes long diameter	.23	.23
Ocellus, long diameter	.09	.10
Ocellus, short diameter	.07	.09
Postclypeus length	.24	.23
Postclypeus width	.49	.51
Postclypeal index	.47	.45
Pronotum length	.42	.45
Pronotum width	.84	.74

A PRACTICAL WORKING KEY TO THE ALATES OF THE NEARCTIC SPECIES OF *AMITERMES* S. STR.

1. **Black** 2
   Dark brown to yellow 3
2. **Very dark shining black; muscle markings hardly visible; fontanel more than half as wide as long** .... **Amitermes emersoni** Light
   Smoky black; muscle markings visible; fontanel less than half as wide as long; postclypeus with a few light spots marking location of large hairs .... **Amitermes coachellae** Light
3. **Very light; yellow** .... **Amitermes pallidus** n. sp.
   Darker; brown to light brown below; brown above 4

4. Larger, head wider than 1.05 mm........................**Amitermes silvestrianus** Light
   Smaller, head less than 1.00 wide..5
5. Head width not more than 0.90 mm..6
   Head width more than 0.90 mm...7
6. Darker; body larger, wings shorter, head width about 0.90 mm., wings about 6 mm. long; head more rounded and wider in proportion.................................
   ....**Amitermes minimus** n. sp.
   Lighter; body smaller, wings longer; head width 0.85 mm. or less; wings more than 6 mm. long; head narrower and with straight sides......................
   ....**Amitermes parvulus** n. sp.
7. Fontanel very small...**Amitermes parvipunctus** n. sp.
   Fontanel large 8
8. Fontanel long and narrow; venter pale................**Amitermes wheeleri** Desneux
   Fontanel broad, with pointed ends; venter brown....**Amitermes spadix** n. sp.

Gnathamitermes n. subgen.

DIAGNOSIS

Alate.—Large, more than 13 mm. long with the wings; generally brown in color; postclypeus about half as long as broad; fontanel oval, more or less obscured by posterior infuscation; preceded by a narrow yellowish line which is in contact with its anterior margins; eyes separated from lower margin by about one-half their diameter; antennae of sixteen segments; pronotum about half as long as broad.

Soldier.—Relatively large; head width 1.10 mm. or more; head low, broad, rectangular or subrectangular, nearly as wide as long (head index about 0.95); mandibles long; head-mandible index never below 0.85 and typically about 1.00; mandibles relatively straight, curved but little save at tip and not strongly so there; teeth near middle, relatively small, variable in shape, often different on two mandibles and set in shallow notch in mandible.

Type species.—Amitermes perplexus Banks.

Four species belonging to this subgenus were described by Banks (1920), *A. tubiformans* Buckley, *A. arizonensis* Banks, *A. perplexus* Banks, and *A. confusus* Banks. The alate of *A. tubiformans* is not definitely known. The alates ascribed to *A. arizonensis* and on which the species was based have been shown earlier in this paper to belong to *A. wheeleri* Desneux and therefore the name *A. arizonensis* passes into the synonomy of that species. An examination of the collections from Texas, Arizona, and California show several apparently distinct types. The material is limited and often from widely separated localities. Study of more complete series may show these types to represent, in some cases or in all, geographical subspecies or even the variations of a single plastic species. At present they are not known to intergrade and the only logical course is to consider them to be separate species.

SPECIES ALLOCATED TO *Gnathamitermes* NEW SUBGENUS

Amitermes acrognathus n. sp.
Amitermes acutus n. sp. Alates unknown.
Amitermes confusus Banks. Soldiers unknown.
Amitermes fuscus n. sp. Soldiers unknown.
Amitermes grandis Light. Alates unknown.
Amitermes infumatus Light. Alates unknown.
Amitermes magnoculus n. sp. Soldiers unknown.
Amitermes nigriceps Light. Alates unknown.
Amitermes perplexus Banks.
Amitermes tubiformans Buckley.

As the table given below of the indices of the soldiers of the Nearctic species will show, the soldiers of these species differ distinctly among other characters in the location of the teeth on the mandibles, relative length of the mandibles, and degree of curvature of the mandibles.

INDICES FOR THE SOLDIERS OF THE NEARCTIC SPECIES OF *Gnathamitermes*

Species	Right tooth	Head-mandible	Mandible curvature	Head	Head height
A. perplexus Banks..........	0.36	1.00	0.043–0.053	0.87–0.95	0.50–0.62
A. acutus n. sp..................	0.33–0.35	1.00–1.07	0.033–0.041	0.90–0.95	
A. acrognathus n. sp.......	0.41	0.95–1.00	0.049	0.90–0.95	0.60–0.65
A. infumatus Light..........	0.38–0.45	0.95	0.071–0.077	0.90–0.95	0.57–0.66
A. tubiformans	0.47	0.85	0.062	0.95	0.66

I had been early impressed with the peculiar situation as regards the alates described by Banks as *A. confusus* and *A. perplexus.* A considerable range of experience in collecting termites in various regions and in studying collections made by others had convinced me that, save where the collecting was done only about lights, if any species was taken several times, particularly if in different areas, soldiers (and workers or nymphs) or complete nest series would be taken far more times than alates alone, indeed that it was extremely unlikely that alates only of a species would be taken a number of times without the other castes showing up in the collections. Of course it might easily be true that a species could be taken once or twice swarming and not be taken in colony collections, but if common enough to be taken several times and in different regions it would be common enough to appear in the colony collections. This does not entirely eliminate, of course, those cases in which, although the alates and the other castes of a species are present in the collections, they are not

taken together but the fact that alates are taken swarming indicates their presence in the colonies and makes it very probable that collections made at that time will include them.

Further doubt was cast on this situation by observations of final instar nymphs of the first form reproductives of our seven California species of *Amitermes*. These showed that there was a positive correlation between the size of the soldiers and the workers of a species and these nymphs and therefore of the alates. Yet here were the two largest species in our region as regards their soldiers, *A. tubiformans* and *A. arizonensis*, associated with very small alates, while two species of very large alates were without known soldiers and workers.

The hypothesis was set up, therefore, that *A. confusus* and *A. perplexus* were alates of the *tubiformans* group, probably the alates of *A. arizonensis* and *A. tubiformans* respectively, and that the alates ascribed to these two species by Banks belonged to some other species, known or unknown. As will be seen, this hypothesis has been substantiated in general, the alates described as *A. perplexus* by Banks proving to belong with soldiers belonging to my former *tubiformans* group (new subgenus *Gnathamitermes*), although not to *A. tubiformans* whose alate is not yet identified, and while *A. confusus* Banks has not been identified with soldiers it almost certainly represents the alates of one of the species of this group based on soldiers only, probably *A. acutus* n. sp.

These species are closely related and form a compact group. I shall give first a more extended description of *A. perplexus* Banks which is well represented in nest series and make the other descriptions brief and diagnostic. The descriptions are accompanied by careful line drawings, all to the same scale, designed to bring out the characters on which the species are based.

So far as known the habits are much the same for all the species of this group. Further observations and collections with determination of species will be necessary to bring out any specific differences in habit.

They are nearly always desert or arid-land dwellers, addicted to the building of earthen tubes around small vegetation or galleries over larger pieces which, contrary to the habits of most termites, they attack from the outside. Indeed, in the case of wooden structures or stalks of shrubs, they eat away only the very thin weathered outer

portion and the whitened surface areas exposed when the galleries are blown or washed away are a characteristic sight in much of the desert Southwest.

KEY TO THE SPECIES OF THE SUBGENUS *GNATHAMITERMES*

ALATES

1. Small; head 1.15 mm. wide through the eyes or less; head narrow; ocellus separated from eye by its long diameter......................**A. acrognathus** n. sp.
   Large; head more than 1.20 mm. wide through the eyes; head broad............2
2. Eyes and ocelli of medium size; eye separated from posterior margin of head by twice its long diameter or more...3
   Eyes and ocelli large; eye separated from posterior margin of head by less than twice its long diameter..**A. magnoculus** n. sp.
3. Dark brown...4
   Light brown; fontanel and muscle markings distinct.........**A. confusus** Banks
4. Smoky brown; fontanel conspicuous, triangular; muscle markings conspicuous..**A. fuscus** n. sp.
   Shining mahogany brown; fontanel and muscle markings obscure........................ ....**A. perplexus** Banks

SOLDIERS

1. Teeth below middle of mandibles, of various types but not both shelf-like......2
   Teeth at middle of mandible; both shelf-like (fig. TT)... ....**A. tubiformans** Buckley
2. Mandibles sharply narrowed at about tooth level, very slender distally; teeth but little below middle; neither tooth in notch....**A. acrognathus** n. sp.
   Mandibles not especially narrowed at tooth level; teeth considerably below middle; right tooth at least in a notch..3
3. Head subrectangular; mandibles little if at all bent in at level of teeth......4
   Head ovate, sides strongly convergent in front; mandibles distinctly inbent at level of teeth...**A. grandis** Light
4. Mandibles considerably shorter than head............................**A. nigriceps** Light
   Mandibles as long or nearly as long as head..5
5. Mandibles not longer than head; tips markedly inbent; mandibles distally dark smoky red (head of worker smoky)..........................**A infumatus** n. sp.
   Mandibles as long as or longer than head; tips not strongly inbent; mandibles not distally smoky (head of worker yellow)...6
6. Sides of head strongly convex; head distinctly broadened in front of middle; mandibles strongly contracted near base with a distinct convexity just below tooth on each mandible; right tooth very acute; distally directed ....**A. acutus n. sp.**
   Head subrectangular, sides faintly convex; mandibles much less strongly contracted basally; tooth less acute, directed inward......**A. perplexus** Banks

Under natural conditions the workers of these species have a characteristic transparent, swollen, fluid-filled appearance different from that of any other termite known to me and which is quickly lost on handling and disappears at once on killing in alcohol.

In spite of the fact that these termites make their home in or on the margins of the desert or semi-desert areas of the Southwest, they are very susceptible to drying and high temperatures, dying on exposure to the sun for a period of minutes or even seconds in midsummer, and are not therefore really desert animals. Mr. O. L. Williams has found, by means of buried instruments, that the moisture and temperature are practically constant at a depth of 48 inches, the air being saturated and the maximum temperature in May about 76° F when the maximum external temperature runs up to 101° F. At this time of year the air in the tubes was found to have a saturated moisture content in the early morning and practically the same as that of the external atmosphere during the middle of the day and the termites were found in their tubes in the early morning but not during the day. During the winter months the diurnal migration is reversed, the cold of the night period drives the termites down and they are found in their outer workings only during the latter portions of the day, retreating again at the evening chill. These observations were made on *A. perplexus* or *A. acutus,* possibly both, in the Coachella Valley region of southeastern California.

Fortunately several collections by F. M. Gaige which were kindly given me for study by Dr. Emerson are nest series with alates, soldiers, and workers. Most of the collections, however, consist of alates alone or of soldiers and workers. It is to be expected therefore that some of the species described will later fall into synonymy because of the association of alates and soldiers now described as separate species.

Amitermes perplexus Banks

Figures BB–FF, OO and PP

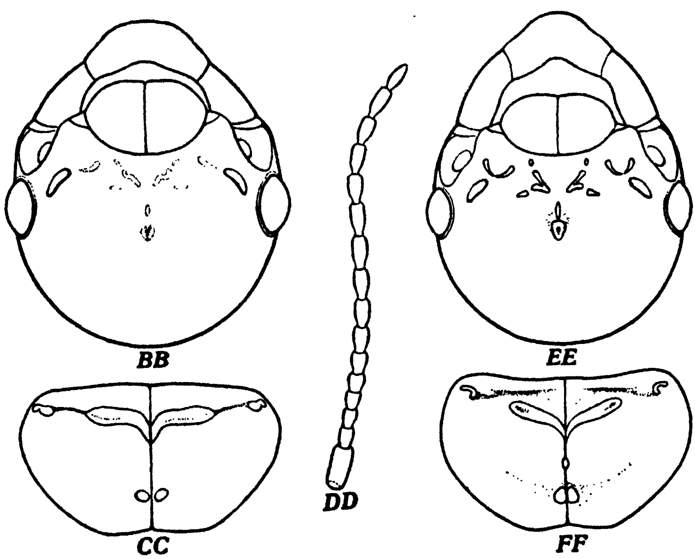
Amitermes perplexus Banks and Snyder 1920.
Amitermes arizonensis Banks and Snyder 1920 (soldiers in part at least).
Amitermes arizonensis Light 1930*a* (in part).

Material studied.—Nest series with alates from Phantom Lake, Jeff Davis County, Texas (Gaige); soldiers from Coachella Valley, California (Castle, Emerson, Light, Pickens), Sabino Canyon, Arizona (Hofer); alates from Victoria and Sonora, Texas (Snyder), Verde Valley and Jerome, Arizona (W. W. Jones), Phoenix, Arizona (H. Behoteguy), and Sabino Canyon, Arizona (Hofer).

Descriptions

Alate.—Generally brown; head shining mahogany brown; pronotum lighter, rusty brown; posterior parts of meso- and metanota, distal half of antennae, the costal strip of the wings, the edges of the basal branches of the cubitus, and the abdominal tergites smoky brown; abdominal sternites yellow in center, laterally light smoky brown; postclypeus yellow, more or less overcast with pale smoky brown; labrum, bases of antennae, bases of mandibles, palpi, and legs yellow; distal portions of mandibles dark reddish black.

Head (figs. BB and EE) with straight parallel sides; posterolateral corners rounding very broadly into flatly convex posterior margin.



Figures BB–FF. Alates of *Amitermes perplexus* Banks. All figures *ca.* × 25.

Fig. BB. Head of alate from Texas nest series.
Fig. CC. Pronotum of same.
Fig. DD. Antennae of same.
Fig. EE. Head of alate from Verde Valley, Arizona.
Fig. FF. Pronotum of same.

Fontanel often obscure or entirely invisible; when visible (fig. EE) relatively small, nearly round, more or less infuscated behind; preceding line more than half as long as fontanel. Muscle markings usually obscure save transverse which are crescentic.

Postclypeus narrow and long; hardly twice as wide as long; flatly swollen; anterior margin straight; sides strongly convex, rounding broadly into narrow, flat, or faintly biconvex posterior margin.

Eyes small, somewhat elongated; separated from ventral margin of head by about half their long diameter, from the dorsal margin by somewhat less than their short diameter, and from the posterior margin by twice their long diameter or a little more.

Ocelli somewhat variable in size, about half as long as diameter of eye, elongated, narrowed in front, separated from eye by about long diameter.

Antennae of sixteen segments; as in figure DD.

Pronotum as in figures CC and FF; sides convex; posterior margins clearly biconvex; considerably longer than half its width.

MEASUREMENTS OF ALATES OF *Amitermes perplexus* Banks

	Texas A	Texas B	Phoenix	Verde Valley	Sabino, Arizona	Sonora Texas
Length with wings	16.20	16.00	16.00	14.51		
Forewing length	13.00	13.00	12.50	11.00	11.00	
Head length over all	1.68	1.71	1.80	1.71	1.68	1.62
Head capsule length	1.11	1.08	1.11	.99	1.08	1.02
Head width, through eyes	1.26	1.26	1.32	1.32	1.26	1.23
Eye, long diameter	.29	.29	.32	.29	.29	.28
Ocellus, long diameter	.15	.17	.15	.12	.13	.12
Ocellus, short diameter	.12	.10	.12	.09	.09	.10
Postclypeus length	.30	.32	.38	.29	.35	.35
Postclypeus width	.67	.61	.61	.61	.60	.61
Postclypeal index	.45	.49	.62	.48	.58	.57
Pronotum length	.72	.72	.81	.66	.78	.66
Pronotum width	1.23	1.32	1.38	1.32	1.26	1.23

Soldier.—Head and bases of mandibles yellow; mandibles save bases pale red to smoky red; antennae basally whitish, distally pale to moderately dark smoky black; otherwise whitish.

Head (figs. OO and PP) broad, subrectangular; head index usually 0.90 or more; sides somewhat convex to nearly straight; postero-lateral corners rounded; posterior margin more or less convex; head low, highest behind middle; head height index about 0.50–0.60; head sloping gradually from highest point to clypeus; fontanel projection scarcely visible in profile; ventral margin curving strongly upward in distal one-half.

Fontanel located near front of head, about as far behind level of antennae as mandibular articulation is in front of it; directed forward; its upper margin very faintly infuscate and marked by a row of longer hairs.

Postclypeus and anteclypeus bilobed. Labrum triangular; tip acute, sides weakly convex. Antennae of fifteen segments.

Mandibles (figs. OO and PP) as long as or slightly longer than the head; nearly straight save at tip; tips of both somewhat incurved; not humped at tooth level; teeth conspicuous, at about same level; left tooth prominent, triangular; posterior face short, distal face long, continuous with internal border of mandible (fig. OO) or shorter and set off by a distal notch (fig. PP); right tooth prominent, directed inward, acute (fig. OO) or triangular (fig. PP), preceded by a distal notch into which tooth of left mandible fits when mandibles are crossed.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIERS OF *Amitermes perplexus* Banks

	Redlands	Coachella Valley	Texas A	Texas B	Texas C	Sabino Canyon, Arizona
Head length	1.32	1.26	1.38	1.35	1.32	1.29
Head width	1.20	1.14	1.20	1.26	1.20	1.14
Head height	.69	.78	.72	.84		.78
Right mandible, length	1.32	1.26	1.32	1.35	1.32	1.32
Right tooth, height	.46	.48	.48	.51	.48	.45
Left mandible, length	1.30	1.25		1.36		1.36
Mandible curvature, minimum	.054	.054		.058		.07
Gular length	.72	.54	.73	.73		.54
Gular width, maximum	.43	.35	.35	.35		.32
Gular width, minimum	.32	.38	.33	.32		.33
Gular width, posterior	.35	.39	.38	.38		.34
Head index	.91	.90	.87	.93	.95	.88
Head height index	.52	.62	.52	.62		.60
Head-mandible index	1.00	1.00	.96	1.00	1.00	1.02
Right tooth index	.35	.38	.36	.38	.36	.36
Mandible curvature index	.044	.047		.043		.053

Variation.—The alates assigned to this species exhibit very considerable variation in general size and color, in degree of visibility and pattern of the muscle markings, in size of fontanel, and in size and shape of ocelli. Fortunately a nest collection with soldiers agreeing perfectly with those of the collection on which the description is based (Gaige 158) contains alates showing the extremes of these variations.

The soldiers varied so considerably as to toothing as to make it seem necessary at first to constitute a separate species for those from California and Arizona in which the two teeth are somewhat similar and the notchings much more conspicuous (fig. PP). The remarkable agreement in dimensions brought out by the measurements and indices between these soldiers and those from Texas makes this unwise at present, although careful study of complete series may later indicate the existence of geographic subspecies.

Biology.—Nothing is definitely known as to the biology of the Texas collections and field observations in California and Arizona have not been definitely enough connected with available collections to make it possible to discuss their habits, although it seems practically certain that they are builders of earthen tubes and galleries over desert plants and other available food material.

The swarming dates known are June 27 at Jerome, Arizona (Jones), June 28 at Sabino Canyon, Arizona (Hofer), July 12 at Phoenix, Arizona (Behoteguy), and August 12 at Sonora, Texas (Snyder). Alates were found in the colony by Gaige at Phantom Lake, Texas, on June 1 and July 7.

Amitermes acutus n. sp.

Figure SS

?*Termes tubiformans* Desneux 1905.

Collections examined.—Soldiers only, from several points in California: Calexico (E. Y. Porter), Dry Camp (Pickens), Edom (Emerson); two from the Arizona border, Yuma (Porter), Nogales (Snyder); and from the Frenchy Mine near Las Vegas, Nevada (Light).

Descriptions

Alate unknown.

Soldier.—Head (fig. SS) broad ovate, broadest in front of middle; mandibles (fig. SS) as long as or a little longer than head; bent in near bases; convex for a short distance just below teeth; otherwise straight save for weak distal incurvature; mandible curvature index about 0.03 to 0.04; teeth low on mandible, at about basal third, right tooth index about 0.33; teeth small; left tooth low, inconspicuous, with a tiny sharp spine; right tooth sharp, pointed; varying in size from small to moderately large; anterior face short, posterior face long, merging with inner surface of mandible.

Biology.—This species is found in the same general area as *A. perplexus* in California and it is not always certain to which species records refer.

We have a definite record by Pickens that this species builds the remarkable tubes over desert vegetation, mentioned and figured in my paper on the California species (1930*a*). Whether *A. perplexus* has the same habit is not certain.

Amitermes acrognathus n. sp.

Figures GG, HH, and QQ

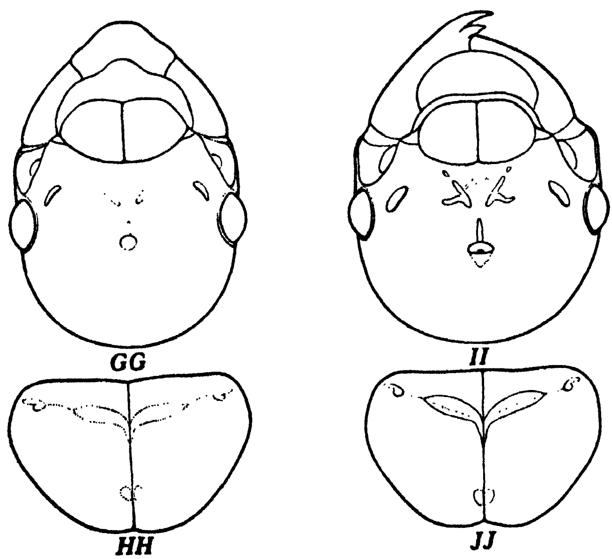
Collections examined.—A single nest series collected by F. M. Gaige at Phantom Lake, Davis Mountains, Texas, June 4, 1918.

Descriptions

Alate.—Color as in *A. perplexus* but generally lighter; head (fig. GG) generally smaller, only about 1.15 mm. wide through the eyes; head narrower, sides straight; fontanel small, round, with a central darker spot; preceding line narrow; muscle markings obscure, when visible transverse confluent with oblique; eyes small; ocelli small, separated from eye by long diameter; postclypeus much as in *A. perplexus;* antennae of sixteen segments, very slender; pronotum (fig. HH) shorter, antero-lateral corners less depressed, otherwise as in *A. perplexus.*

MEASUREMENTS IN MILLIMETERS OF AN ALATE OF
Amitermes acrognathus N. SP. FROM TEXAS

Head length over all	1.56
Head capsule length	1.05
Head width, through eyes	1.14
Eye, long diameter	.23
Ocellus, long diameter	.15
Ocellus, small diameter	.10
Postclypeus length	.29
Postclypeus width	.55
Postclypeal index	.52
Pronotum length	.66
Pronotum width	1.14



Figures GG–JJ. Alates of *Amitermes acrognathus* Light and *A. confusus* Banks. All figures *ca.* × 25.

Fig. GG. Head of *A. acrognathus*.
Fig. HH. Pronotum of same.
Fig. II. Head of paratype of *A. confusus* from Oracle, Arizona.
Fig. JJ. Pronotum of same.

Soldier.—Mandibles (fig. QQ) about as long as head; not inbent at base; broadly and weakly convex at base; distinctly narrowed at about level of teeth; distally narrow and sharp, somewhat incurved gradually from tooth level; tips weakly incurved; teeth small, low, triangular, without notches, but little below middle of mandibles; right tooth index about 0.41.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIERS OF *Amitermes acrognathus* NEW SPECIES

	A	B
Head length	1.26	1.32
Head width	1.14	1.20
Head height	0.78	0.72
Right mandible, length	1.20	1.32
Right tooth, height	0.54	0.48
Left mandible, length	1.19	
Mandible curvature, minimum	0.054	
Gular length	0.67	
Gular width, maximum	0.32	
Gular width, minimum	0.32	
Gular width, posterior	0.36	
Head index	0.90	0.95
Head height index	0.65	0.60
Head-mandible index	0.95	1.00
Mandible curvature index	0.41	0.41

Amitermes fuscus n. sp.

Figures KK and LL

Collections examined.—A single collection consisting of four dealates taken by Mr. D. F. Macpherson on the roof of his house at Beaumont, California, on August 10, 1931.

DESCRIPTION

Alate.—Head, pronotum, and costal margins of wing scales dark smoky brown; remainder of dorsal surface smoky brown; ventral surface yellow to light smoky brown; antennae basally smoky brown, distally smoky black; postclypeus smoky yellow.

Head (fig. KK) with strongly converging sides rounding broadly into the hardly convex posterior margin.

Fontanel triangular (fig. KK) with posteriorly directed apex; center white, sides and preceding line yellow; muscle markings conspicuous, complicated, variable; antennal spot marked by light semicircular line.

Eyes small, separated from posterior margin of head by twice their diameter and from dorsal and ventral margins by more than half their diameter. Ocellus small, lemon-shaped; separated from eyes by about their long diameter.

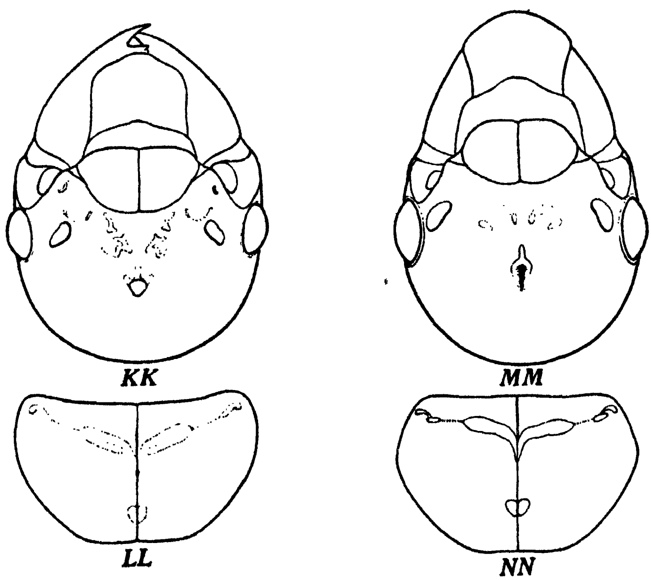
Antennae of sixteen segments; third and fourth small.

Pronotum as in figure LL.

Wings lacking.

MEASUREMENTS OF AN ALATE OF *Amitermes fuscus*
NEW SPECIES

Head length over all	1.50
Head capsule length	1.02
Head width, through eyes	1.26
Eye, long diameter	0.25
Ocellus, long diameter	0.15
Ocellus, short diameter	0.10
Postclypeus, length	0.32
Postclypeus, width	0.70
Pronotum length	0.67
Pronotum width	1.14



Figures KK–NN. Alates of *Amitermes fuscus* Light and *A. magnoculus* Light.
Fig. KK. Head of *A. fuscus.*
Fig. LL. Pronotum of same.
Fig. MM. Head of *A. magnoculus.*
Fig. NN. Pronotum of same.

Systematic position.—This species is marked by its dark smoky color, its small eyes and ocelli, and the conspicuous, triangular fontanel. The dark smoky color indicates that it is probably the alate of *A. infumatus* n. sp. which has been taken at Palm Springs about forty miles south and east. Palm Springs lies on the edge of the desert, however, while Beaumont marks the top of the pass.

Amitermes infumatus n. sp.

Figure RR

Amitermes arizonensis Light 1930*b*.

Alate unknown.

Soldier.—Head light yellow, body whitish; antennae basally pale, increasingly infuscate toward tips; mandibles yellow below teeth, distally smoky red.

Head (fig. RR) short and broad; subrectangular; sides weakly convex; contracted in anterior quarter; postero-lateral corners rounded into weakly convex posterior margin.

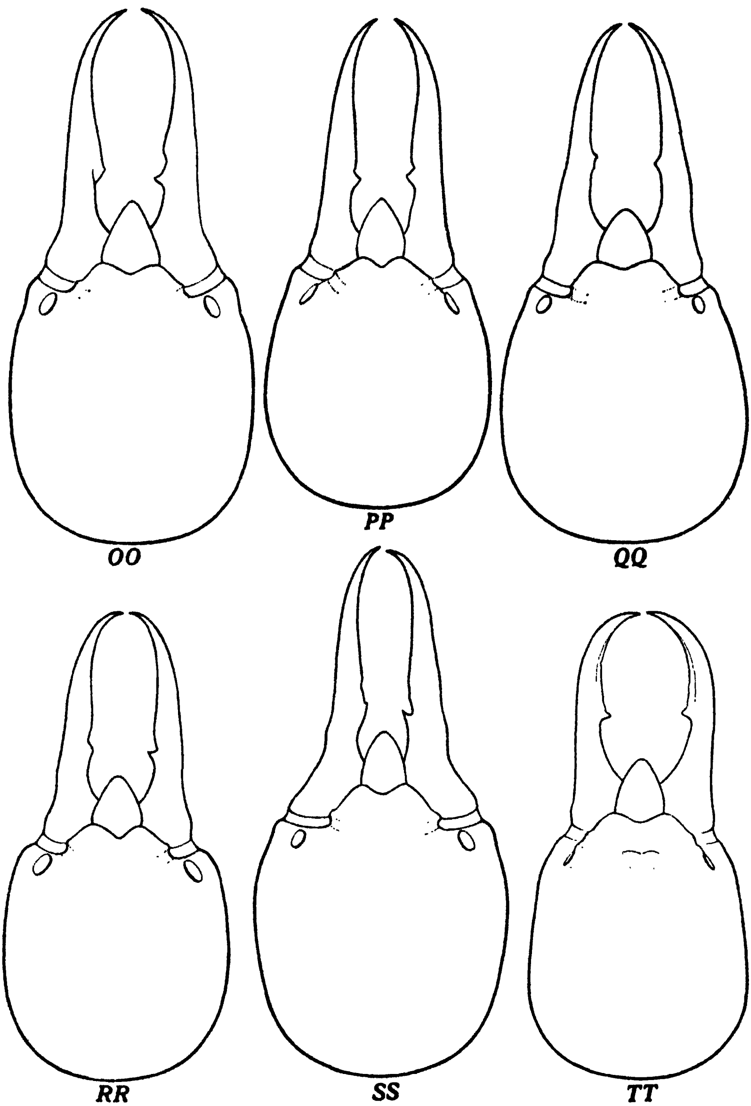
Mandibles (fig. RR) about as long as head; moderately inbent in distal third; bulging slightly at level of teeth; teeth as in figure RR; both distinct and inwardly directed, both in notches, right more acute.

Antennae as in figure RR.

This species was first noted in a single collection made at Presidio, near Mazatlan, Sinaloa, Mexico. An examination of the collections available to me now shows it to be present also in the Coachella Valley, California, at Palm Springs (Light), at Indio (Light), on the western mountain slope of the Imperial Valley (Light), and in the Chocolate Mountains between the Colorado and Mohave deserts at an elevation of 1900 feet (Pickens).

This species is characterized by mandibles somewhat shorter than the head, strongly curved distally (mandible curvature index .071–.077), by toothing similar to that of the California form of *A. perplexus* but with the notch preceding the left tooth more distinct. The workers also have very strongly infuscated heads, the antennae of both castes are dark smoky black, and the mandibles are darker than usual in *A. perplexus.*

Biology.—This species builds earthen tubes over small shrubs, usually over dead portions, over sticks and pieces of wood on the ground, and occasionally builds broader galleries over dead stalks of creosote bush (*Larrea tridentata*). In the lower reaches of the mouth of Tahquitz Canyon, just west of Palm Springs, evidences of their work begin to appear as soon as the rocky zone is reached where the soil is disintegrating granite and from this point, which is not very much above the valley floor, extend for at least several hundred feet to the top of the ridge which forms the north wall of the canyon. The workings are at irregular but frequent intervals, twenty to a hundred feet apart. Altogether at least a hundred instances were noted. In no case were the workings extensive, in no case did they exhaust the



Figures OO–TT. Heads of soldiers of Nearctic species of subgenus *Gnathamitermes*. All figures *ca.* × 25.

Fig. OO. *A. perplexus* Banks from Texas.
Fig. PP. *A. perplexus* Banks from Arizona.
Fig. QQ. *A. aorognathus* Light from Texas.
Fig. RR. *A. infumatus* Light from California.
Fig. SS. *A. acutus* Light from California.
Fig. TT. *A. tubiformans* Banks from Texas.

available supply of material. Indeed in practically all cases the surface showing signs of their attacks was a very small fraction of that available. In the greater number of instances the part attacked was the dead stalks of creosote bush (*Larrea tridentata*) and seldom more than one or two of the five to twenty-five stalks would be attacked and these only over a relatively small portion of their surface. No signs of grouping of these workings were to be made out aside from one or two cases where two were found within a few feet of one another. These individual workings are about what one would expect from small groups of less than a hundred individuals. This situation raises some interesting questions as to the size of colonies, the effective working radius of a single colony, whether the above-ground food sources are the only ones or are secondary to more important underground sources, and whether the wood thus obtained is used directly or as a material for constructing fungus gardens.

Three hypotheses suggest themselves: (1) that there are many small colonies, each working representing the activity of one such colony; (2) that there are a few large colonies covering a wide range in small foraging bands, or (3) that there are many large colonies, the major food supply of which is below ground, the above ground feeding being somewhat secondary.

Superficial appearances point to the correctness of the first hypothesis but it runs counter to our experience which indicates large colonies as characteristic of the family Termitidae in general, of some at least of the other species of *Amitermes*, and even of *A. arizonensis* in other situations.

Superficial appearances do not seem such as would be expected from wide ranging colonies. The distance between workings is relatively great and the difficulties are increased on the boulder-strewn mountain side where progression for fifty feet would probably indicate several times that under ground. The rapidity with which workers tunnel through the fine sand of laboratory cultures is truly amazing. Eight workers left through a relatively cold night in a culture dish full of moist sand not only adjusted themselves to the new situation, but built three covered entrances, and very extensive underground trails by morning. At least five inches of such trails were visible.

In support of the third hypothesis, that the major food supply lies under ground and the above-ground feeding is secondary, is the statement of Snyder (Banks and Snyder 1920, p. 179) concerning the closely related *A. tubiformans* Buckley, that "in the prairie regions

of both Texas and Arizona this termite lives in the ground, feeding on the roots of grass and other vegetation." As further evidence of the secondary nature of the above-ground food supply is the fact that of the many pieces of wood showing signs of previous feeding, only a remarkably small percentage showed signs of present use. It was interesting to note, however, that those pieces on which work was going on or which showed signs of previous use and were partly buried, never showed any sign of attack on the portion under ground. Indeed I have never found this species attacking wood under ground. Its runways ramify extensively though the soil and it is quite possible that roots furnish its food, but for this there seems to be no direct evidence.

While working extensively in the soil this species differs from the species of *Amitermes* s. st. of this region in the lighter color of its abdomen. Not only does there seem to be a much smaller amount of dark material (earth?) in the intestine but under natural conditions the abdomen seems swollen with a clear liquid. This is lost on fixation and indeed on handling, and workers in laboratory colonies have the abdomen much shrunken.

Amitermes confusus Banks

Figures II and JJ

Amitermes confusus Banks and Snyder 1920.

Collections examined.—Paratype individual, Oracle, Arizona (Schwarz); Verde Valley, Arizona (W. W. Jones); Victoria, Texas (Mitchell).

A redescription follows based on a paratype individual from the type collection made by E. A. Schwarz at Oracle, Arizona, July 2.

Alate.—Generally brown, but lighter than in *A. perplexus;* hairing generally very dense; head (fig. II) very broad, sides straight; postero-lateral corners rounding very broadly into broad, weakly convex posterior margin.

Fontanel broad, conspicuous, infuscated behind, anterior end V-shaped, brilliant white; preceding line long, slender; muscle markings conspicuous, as in figure II.

Eyes slightly elongated dorso-ventrally; separated from dorsal and ventral margins of head by about half their diameter and from posterior margin by more than twice its diameter. Ocelli as in *A. perplexus.*

Postclypeus light, not greatly swollen, somewhat more than half as long as wide.

Pronotum (fig. JJ) very similar to that of *A. perplexus.*

Soldier unknown.

MEASUREMENTS OF PARATYPE ALATE OF *Amitermes confusus* BANKS

Length without wings	7.50
Length of forewing	13.50
Head length over all	1.66
Head length	0.86
Head width	1.36
Head height	0.51
Eye, long diameter	0.26
Ocellus, long diameter	0.17
Ocellus, short diameter	0.12
Postclypeus length	0.35
Postclypeus width	0.73
Pronotum length	0.72
Pronotum width	1.18

Discussion.—This species approaches *A. perplexus* very closely and study of more extensive collections may very probably prove it to be the same or it may prove to be the unknown alate of *A. acutus.*

Amitermes magnoculus n. sp.

Figures MM and NN; plate 1, figures 5, 6, 10, and 11

Material examined.—Two collections of alates from Calexico on the southeastern California border (Bennington).

DESCRIPTIONS

Alate.—Generally brown; head light mahogany with a smoky tinge; postclypeus, labrum, palpi, basal joint of antennae, legs, and abdominal sternites yellow to light smoky brown; antennae basally light, distally pale smoky black-brown; pronotum lighter than head, rusty; abdominal tergites smoky brown.

Head (pl. 9, fig. 5; fig. MM) broad; sides straight, rounding very broadly into flatly convex posterior margin.

Fontanel (fig. MM) long oval, broadest in front; centrally marked by a black area of varying size and shape; anteriorly a narrow white V makes a Y figure with a narrow preceding line. Muscle markings as in figure MM; oblique lines short, comma-shaped; transverse lines obscure, short, not touching oblique lines.

Eyes large; not strongly projecting; somewhat elongated antero-posteriorly with truncated antero-dorsal faces; separated from dorsal and ventral margins of head by about half their long diameter and from posterior margin by less than twice their long diameter. Ocelli large; longer than half diameter of eye; not greatly uplifted, separated from the eye by less than their short diameter.

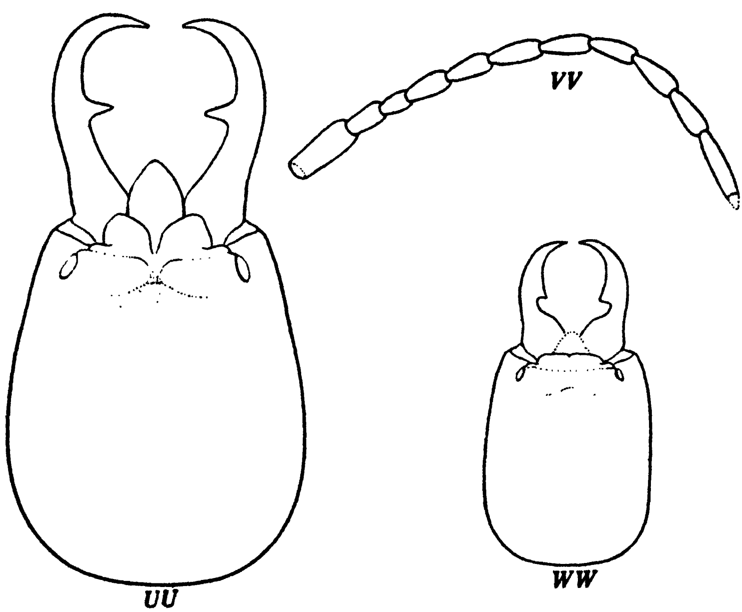
Postclypeus only slightly swollen; otherwise as in *A. perplexus.* Antennae (pl. 9, fig. 5) of sixteen segments, slender; distally narrowed; third segment very short, fourth but little longer.

Pronotum (pl. 9, fig. 6; fig. NN) much as in *A. perplexus.*

MEASUREMENTS IN MILLIMETERS OF AN ALATE OF
Amitermes magnooculus NEW SPECIES

Head length over all	1.74
Head capsule length	1.17
Head width, through eyes	1.30
Eye, long diameter	0.31
Ocellus, long diameter	0.19
Ocellus, short diameter	0.15
Postclypeus length	0.31
Postclypeus width	0.58
Postclypeal index	0.53
Pronotum length	0.75
Pronotum width	1.23

Soldier unknown.



Figures UU–WW. Soldiers of *Amitermes foreli* Wasmann and *Amitermes parvulus* new species.
Fig. UU. Head of mounted paratype soldier of *A. foreli* in dorsal view.
Fig. VV. Antenna of same.
Fig. WW. Head capsule and mandibles of dried soldier of *A. parvulus* in dorsal view.

Biology.—These alates were first taken by Mr. W. L. Bennington at Calexico, California, between 7:00 and 8:00 P.M. on September 11, 1930, following a hard rain, almost a cloudburst, between 4:15 and 5:00 P.M. Attention was first attracted by the large number of wings on the sidewalk and pairs were then found running around. This would seem to indicate that flight had taken place somewhat earlier.

Several alates of *Heterotermes aureus* Snyder were taken with these. Again this year (1931) Mr. Bennington sent me specimens found swarming on the evening of August 4 following a gentle rain of about .5 inch in the afternoon. As before alates of *Heterotermes aureus* were swarming at the same time.

Amitermes tubiformans (Buckley)

Figure TT

Termes tubiformans Buckley 1863, Desneux 1905.
Amitermes tubiformans Wasmann 1902, 1903, Light 1930*b*.
Amitermes tubiformans Banks and Snyder 1920 in part (soldiers and workers).
Hamitermes tubiformans Holmgren 1912.
?*Amitermes perplexus* Banks 1920 (in part perhaps).
Not *Termes tubiformans* Desneux 1905.
Not *Amitermes tubiformans* Banks and Snyder 1920 (alates).

While Buckley's description of this termite (1863) is very inadequate, as Desneux points out, yet the presence of soldier mandibles as long as the head, and the nature of the teeth indicate that he had a species of the *tubiformans* group, the subgenus *Gnathamitermes* as here defined. That it was the species described by Banks (1920) as *A. tubiformans* so far as soldiers are concerned, is indicated by the following characters: (1) "a small tooth about midway on their (mandible) inner margin" and (2) "head oval." The tooth in the soldiers of the other species of the subgenus is distinctly below the middle of the mandible and the head is rectangular or nearly so in those known from the United States. The "Female?" of Buckley is of course a late instar reproductive nymph. It is unfortunate that he did not give measurements since these might perhaps have prevented the confusion of alates, for which Banks is responsible, although Desneux's clean-cut description of the alate of "Termes tubiformans" (1905) did not. A careful consideration of Desneux's description of *Termes tubiformans* (1905) makes it practically certain that the species he describes is one of the other species of the subgenus *Gnathamitermes,* probably *A. acrognathus* n. sp. or *A. perplexus* Banks. He emphasizes the straightness of the mandibles, for example ("presque droites, avec la pointe un peu incurvée. . . . .") and places the tooth at the basal one-third ("vers le premier tiers"). This conclusion is strengthened by the fact that Gaige who collected in the same locality (Fort Davis, Texas) took several colonies of *A. acrognathus* n. sp. and *A. perplexus* Banks but none of *A. tubiformans.*

Desneux himself was in doubt as to the correctness of his identification, "Ce n'est pas sans quelque hésitation que j'ai rapporté à cette espèce les exemplaires que je décris ici . . . . ," and farther on, "Je possède un soldat de l'Arizona, qui diffère à peine de ceux du Texas, et qui appartient sans doute aussi au *T. tubiformans.*"

Whether Desneux's species was *A. tubiformans* or one of the other species of the subgenus, it is difficult to understand why Banks should ignore his description of the alates in which their large size is indicated, for example, by a forewing 12 millimeters in length, while the alates which Banks ascribed to *A. tubiformans* and *A. arizonensis* are only 9 millimeters long with the wings!

In the absence of a nest series it is impossible to assign an alate to *A. tubiformans* (Buckley), although it is possibly represented by *A. confusus* Banks which is based on alates alone. A nest series[4] including alates and soldiers of *A. tubiformans* is much to be desired to settle this question.

That the alates allocated to this species by Banks (1920) do not belong here is clearly shown by the fact that first-form reproductive nymphs of *A. tubiformans* have a head breadth of 1.10 to 1.12 mm. and a pronotum breadth of about 1.10 mm., while the alates supposed by Banks to be those of *A. tubiformans* have a head breadth of about 1.00 mm. and a pronotum breadth of less than 0.8 mm. Earlier in this paper these alates are described as *A. spadix* n. sp.

MEASUREMENTS IN MILLIMETERS, AND INDICES, OF SOLDIER OF *Amitermes tubiformans* (BUCKLEY) FROM TEXAS

Head length	1.32
Head width	1.25
Head height	.87
Right mandible, length	1.14
Height of tooth	.54
Left mandible, length	1.20
Mandible curvature, minimum	.04
Head index	0.95
Head height index	0.66
Head-mandible index	0.85
Right tooth index	0.47
Mandible curvature index	0.062

LITERATURE CITED

Banks, N.

1918. The termites of Panama and British Guiana. Bull. Am. Mus. Nat. Hist., 38:659–667, plate 1, 2 figs. in text.

Banks, N., and Snyder, T. E.

1920. A revision of the Nearctic termites (Banks) with notes on biology and geographic distribution (Snyder). U. S. Nat. Mus. Bull., 108:1–228, plates 1–25, 70 figs. in text.

Buckley, S. B.

1863. Descriptions of two new species of termites from Texas. Proc. Ent. Soc. Philadelphia, 1 (1862): 212–215.

Emerson, Alfred

1925. The termites of Kartabo Bartica District, British Guiana. Zoologica, 6:291–459, 71 figs. in text.

Desneux, J.

1905. Varieties termitologiques. Ann. Soc. Ent. Belg., 49:336–360.

Holmgren, Nils

1912. Termitenstudien 3. Systematik der Termiten. Die Familie Metatermitidae. K. Svenska Vetensk. Akad. Handl. 48:1–166, pls 1–4, 88 figs. in text.

Light, S. F.

1929. Termites and termite damage. Univ. Calif. Agr. Exp. Sta., Circular 314.

1930*a*. The California species of the genus *Amitermes* Silvestri (Isoptera) Univ. Calif. Publ. Entom., 5:173–214, plates 10–15, 31 figs. in text.

1930*b*. The Mexican species of *Amitermes* Silvestri (Isoptera). Univ. Calif. Publ. Entom., 5:215–232, plates 16–18.

1931. The termites of Nevada. Pan-Pacific Entomologist 8:5–9.

——, Randall, M., and White. F.

1930. Termites and termite damage with preliminary recommendations for prevention and control. Univ. Calif. Agr. Exp. Sta., Circular 318.

Silvestri, F.

1901. Nota preliminare sui Termitidi Sud-Americana. Boll. Mus. Zool. Anat. Comp. Torino, 18:1–8.

1903. Contribuzione alla conoscenza dei Termitidi e Termitofili dell' America meridionale. Redia 1:1–234.

1923. Descriptiones termitum in Anglorum Guiana. Zoologica, 3:307–321, plates 11–15 in text.

Wasmann, E.

1902*a*. Species *novae* Insectorum Termitophilorum ex America Meridionali. Appendix ad Termitorium notitiam. Tijdschr. v. Ent. 45:95–107, pl.9.

1902*b*. Termiten, Termitophilen und Myrmekophilen. Zool. Jahrb. Abt. Syst. 17:99–164.

EXPLANATION OF PLATES

PLATE 9

Photomicrographs of American species of *Amitermes* Silvestri. (Figures 1–6 at same magnification.)

Fig. 1. Head of alate of *Amitermes* (*Amitermes*) *silvestrianus* Light.

Fig. 2. Pronotum of same.

Fig. 3. Head of alate of *A.* (*A.*) *minimus* Light.

Fig. 4. Pronotum of same.

Fig. 5. Head of alate of *A.* (*Gnathamitermes*) *magnoculus* Light.

Fig. 6. Pronotum of same.

(Figures 7–9 at same magnification.)

Fig. 7. Mandibles of alate of *A.* (*A.*) *minimus* Light.

Fig. 8. Mandibles of alate of *A.* (*A.*) *silvestrianus* Light.

Fig. 9. Mandibles of alate of *A.* (*G.*) *magnoculus* Light.

(Figures 10–13 at same magnification.)

Fig. 10. Forewing of *A.* (*G.*) *magnoculus* Light.

Fig. 11. Hindwing of same.

Fig. 12. Forewing of *A.* (*A.*) *silvestrianus* Light.

Fig. 13. Hindwing of same.

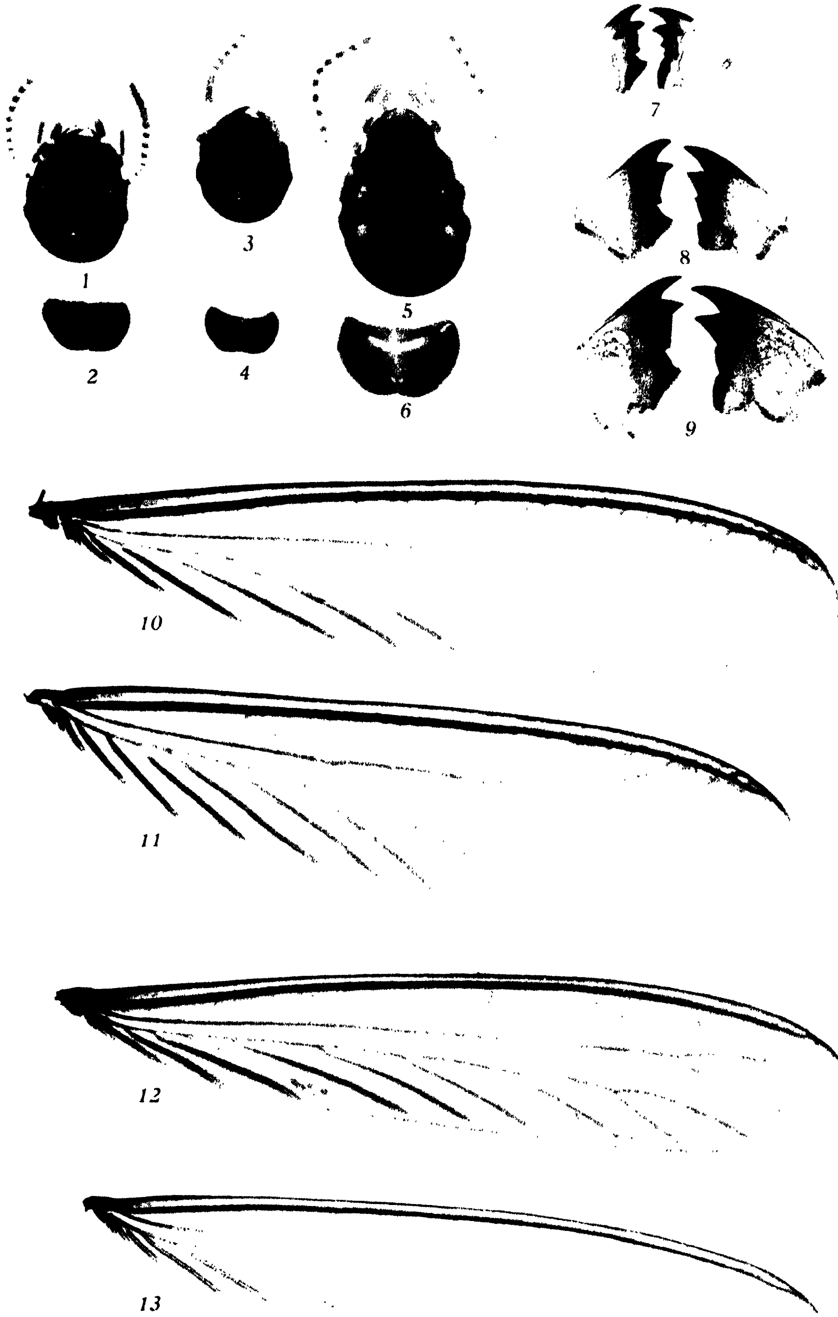

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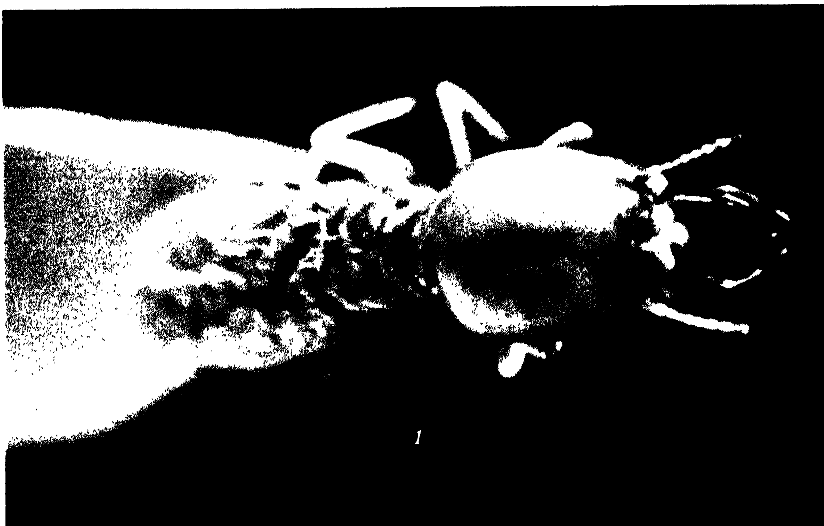
PLATE 10

Photomicrograph of a mounted paratype soldier of *Amitermes foreli* Wasmann.

Fig. 1. In dorsal view with head in horizontal position.

Fig. 2. In side view.



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